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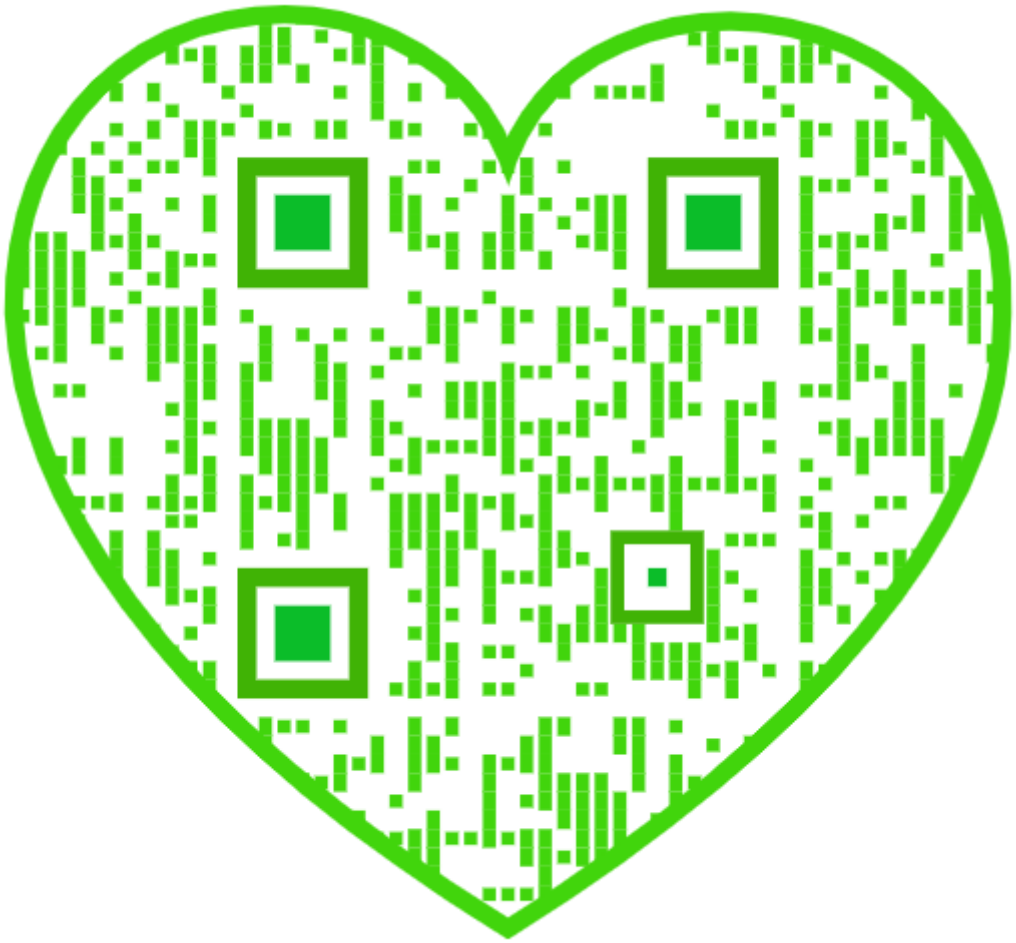

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 144.

A. D. MELVIN, CHIEF OF BUREAU.

# INVESTIGATIONS RELATIVE TO ARSENICAL DIPS AS REMEDIES FOR CATTLE TICKS.

BY

B. H. RANSOM, PH. D.,
*Chief of the Zoological Division,*
AND
H. W. GRAYBILL, D. V. M.,
*Assistant Zoologist.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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# LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
*Washington, D. C., August 12, 1911.*

SIR: I have the honor to transmit, and to recommend for publication in the bulletin series of this bureau, the manuscript of a paper entitled "Investigations Relative to Arsenical Dips as Remedies for Cattle Ticks," by Drs. B. H. Ransom and H. W. Graybill, of the Zoological Division.

One of the most important phases of the problem of dealing with the Texas fever tick is the finding of some effectual means of ridding cattle of the parasites. When large numbers of animals are concerned the most practical way of doing this is by dipping them in some substance that will destroy the ticks. A large variety of dips have been tried in this and other countries, but it has been difficult to find one that will kill the ticks without causing more or less injury to the cattle harboring them.

The experiments described in this bulletin indicate that arsenical dips, when properly compounded and used, furnish the best means yet devised for the purpose, as they are effective in destroying the ticks and at the same time least objectionable in their effects upon the cattle.

Respectfully,

A. D. MELVIN,
*Chief of Bureau.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

# CONTENTS.


| | Page. |
|---|---|
| Introduction | 7 |
| Composition of the dips used in the experimental work | 9 |
| Details of the experiments | 10 |
| Arsenic, soda, and pine-tar dips | 10 |
| Arsenic, soda, and pine-tar dip containing emulsified crude petroleum | 33 |
| Arsenic and zinc-sulphate dip | 34 |
| Arsenic-alum dip | 36 |
| Sodium-arsenate dip | 37 |
| Sodium-sulpharsenite dip | 38 |
| Potassium-arsenite dip containing soap | 38 |
| Effect of repeated applications of the arsenic, soda, and pine-tar dip | 44 |
| Discussion of results | 47 |
| Effects of arsenical dips on cattle | 47 |
| Effects of arsenical dips on ticks | 49 |
| Female ticks | 51 |
| Male ticks | 58 |
| Nymphs and larvæ | 59 |
| The protective action of arsenical dips | 60 |
| Practical significance of results of experiments with arsenical dips | 61 |
| Composition of the dip | 61 |
| Method of application | 62 |
| Number and frequency of applications | 63 |
| Handling the cattle | 64 |

# ILLUSTRATIONS.

PLATES.


Page.

PLATE I. One hundred and twenty-three engorged female ticks after dipping in an arsenical solution ..... 12

II. One hundred and five engorged female ticks collected on the same date as those shown in Plate I and kept under the same conditions but not dipped ..... 12

III. Fig. 1.—Fifty-seven engorged and nearly engorged female ticks collected from a calf immediately after dipping in an arsenic and pine-tar solution. Fig. 2.—Seventeen engorged female ticks collected from an undipped calf ..... 16

IV. Fig. 1.—Seven fully engorged and 17 partially engorged female ticks collected from a calf the next day after dipping in an arsenic and pine-tar solution. Fig. 2.—Engorged female tick collected from an undipped calf ..... 16

V. Fig. 1.—Seven fully engorged and 10 partially engorged female ticks collected from a calf two days after dipping in an arsenic and pine-tar solution. Fig. 2.—Five fully engorged and three partially engorged female ticks collected from an undipped calf ..... 18

VI. Fig. 1.—Fifty-one engorged female ticks after dipping in an arsenic and pine-tar solution. Fig. 2.—Forty engorged female ticks collected from an undipped calf ..... 18


TEXT FIGURE.


Fig. 1. Plan of draining pen for cattle after dipping ..... 65

# INVESTIGATIONS RELATIVE TO ARSENICAL DIPS AS REMEDIES FOR CATTLE TICKS.

## INTRODUCTION.

It is now a well-known fact that the Texas-fever tick may be eradicated from cattle and pastures by following a certain course of procedure in which the cattle are moved from time to time from one pasture to another; in other words, eradication may be accomplished by so-called "rotation methods" without the necessity of treating the cattle with tick-killing substances. In many instances, however, it is impracticable, uneconomical, or on some other account undesirable to depend upon the automatic eradication which ultimately takes place when proper rotation methods are followed. Therefore it becomes necessary in such cases either to use them in connection with other methods or to resort to other methods alone. The dipping or spraying of cattle with a substance destructive to ticks provides a means of hastening eradication and of rendering it possible in the presence of conditions under which unmodified rotation methods would be practically out of the question.

Ever since the fact that the tick is the agent of transmission of Texas fever was established, investigations have been carried on under the auspices of the Bureau of Animal Industry, State agricultural experiment stations, and other institutions for the purpose of discovering some substance which, when applied externally to the bodies of tick-infested cattle, would free them from ticks without injury to the animals themselves. Very early in the history of these investigations it was found that ticks were highly resistant to treatment, and it has been determined that several remedies which give good results in the case of such external parasites as mange mites and lice are of little or no use in the case of ticks. Some substances appeared to have absolutely no effect and others, when applied at a sufficient strength to destroy the ticks, were so severe in their effects upon the cattle that they could not be used in practice. For example, lime-and-sulphur, tobacco, and coal-tar dips, which are very satisfactory remedies against certain other external parasites of cattle, have been found to have no practical value in the destruction of ticks. Oil dips have proved more successful, and for several years crude

petroleum, provided it conformed to certain requirements as to its physical and chemical characteristics, has been recognized by the live-stock sanitary authorities of the Federal Government and of various States as an efficacious remedy against cattle ticks. However, although the efficacy of crude petroleum is generally admitted, there are a number of more or less serious objections to it which have largely interfered with its usefulness. Among these objections may be mentioned the facts that in practice crude petroleum of proper composition is difficult to procure, is rather expensive, bulky, liable to loss by leakage, is frequently very severe in its effects upon cattle, and produces a greasy condition of the hair and skin which is highly undesirable in the case of dairy cattle.

About six years ago the Bureau of Animal Industry began investigating arsenical solutions with reference to their utility for dipping cattle to free them from ticks. At that time arsenical dips as remedies against ticks had been considerably used in South Africa, and to some extent in Australia and South America, but practically not at all in the United States. In 1906, following the publication of two articles[1] by Dr. N. S. Mayo, at that time chief veterinarian of Cuba, in which an arsenical solution was highly recommended as both efficacious against ticks and noninjurious to cattle, a number of trials of arsenical solutions were made in Texas, at first under cooperation between the Bureau of Animal Industry and the live-stock sanitary commission of Texas and later by the Bureau of Animal Industry working alone. The composition and method of preparing the arsenical solution as described by Mayo, in the first article referred to, are as follows:

| | |
|---|---|
| White arsenic | 1½ pounds. |
| Sodium carbonate, crystals | 4½ pounds. |
| Yellow soap | 4½ pounds. |
| Pine tar | 1 quart. |
| Water | 100 gallons. |

The arsenic is to be dissolved in 5 or more gallons of water by boiling for one-half hour; when dissolved add it to 20 gallons of water. Shave the soap, mix with the soda and dissolve in 5 gallons of water. When dissolved, add the tar in a fine stream and stir until the tar is in solution, then mix with the arsenical solution and add sufficient water to make 100 gallons.

In the second article referred to, which appeared about a month later, Mayo gave a somewhat different formula, but essentially the same method for preparing the arsenical dip, as follows:

| | |
|---|---|
| Arsenious acid | 8 pounds. |
| Soda carbonate, crystals | 24 pounds. |
| Yellow soap | 24 pounds. |
| Pine tar | 1 gallon. |
| Water | 500 gallons. |

[1] Breeder's Gazette, vol. 44, No. 11, p. 564, and American Veterinary Review, vol. 30, No. 2, pp. 243-245.

Dissolve the arsenic in 20 gallons or more of water by boiling for 30 to 40 minutes. When dissolved, add to 100 gallons of water. Dissolve the soap and soda in 20 gallons of boiling water, first shaving the soap, and while boiling add the pine tar in a thin stream and stir until it is dissolved. Mix this with the arsenical solution and add sufficient water to make 500 gallons.

In the course of the first year's trials of the dip in Texas Dr. Mayo's formula was slightly modified by the omission of the soap, which did not seem to add to the efficacy of the dip. The formula and method of preparation which were usually employed were as follows:

| | |
|---|---|
| White arsenic | 8 pounds. |
| Sodium carbonate | 24 pounds. |
| Pine tar | 1 gallon. |
| Water sufficient to make | 500 gallons. |

The arsenic and sodium carbonate were dissolved by boiling in 25 or 30 gallons of water, after which the fire was drawn and the solution allowed to cool somewhat. The tar was then added, and finally the mixture was added to sufficient water to make 500 gallons of dip.

During 1906 about 12,000 head of cattle were treated in Texas with the arsenical dip under the supervision of inspectors or agents of the Bureau of Animal Industry with results which in some respects were highly encouraging. Though it appeared questionable from the reports of these dippings whether the dip was absolutely efficacious, there seemed to be no doubt as to its highly destructive action on ticks and, as compared with crude petroleum, its slight injurious effects upon cattle. In fact, the apparent merits of the dip were such that its use was enthusiastically adopted by cattle owners in Texas and has been continued up to the present time, the range of popularity of the dip increasing from year to year.

In consequence of the promising results secured in the first trials of the arsenical solution, the Bureau of Animal Industry has carried out a number of investigations and experiments in order to obtain definite data relative to the efficacy of arsenical solutions as remedies against ticks.

## COMPOSITION OF THE DIPS USED IN THE EXPERIMENTAL WORK.

In most of the experiments the arsenical solution used was compounded in accordance with the modification of Dr. Mayo's formula given above, the amounts of arsenic varying from 8 to 12 pounds, and of sal soda from 24 to 45 pounds, for each 500 gallons of dip, in different instances. When pine tar was used it was added in the proportion of 1 gallon to each 500 gallons of dip. In some of the experiments arsenical dips of somewhat different composition were used. The amount of arsenic in solution in the various dips, expressed in its equivalent of arsenic trioxid, varied from 0.16 to 0.495 per cent.

In the Mayo dip and its modifications the arsenic is present in the form of a sodium salt known as sodium arsenite, which results from the chemical reaction which takes place between the arsenic (arsenic trioxid) and the sal soda (sodium carbonate) when these substances are boiled together. It has been found by Aubrey V. Fuller,[1] of the Biochemic Division of this bureau, that under certain conditions the sodium arsenite in an arsenical dip becomes more or less completely oxidized to sodium arsenate, this change occurring after the lapse of several weeks, a fact of great practical importance, since sodium arsenate seems to be weaker in its action upon ticks than is sodium arsenite.

In the experiments recorded in the present paper the arsenic in the dips used was in solution as arsenite unless otherwise stated, and was known so to be either because the dips were used fresh or because the dips were afterwards proved by chemical analysis to be unoxidized.

The proportionate amount of sal soda used in the arsenic, sal soda, and pine-tar mixture is more than is necessary to transform the arsenic into sodium arsenite. It has not been determined whether a dip containing an excess of soda is more efficacious than one in which just enough soda has been used to complete the reaction with the arsenic. In view of the fact, however, that the cuticle of ticks is softened and may be dissolved by alkaline solutions, it is possible that the efficacy of the dip may depend in part upon the weak alkalinity given to it by the excess of soda used in its preparation. The function of the pine tar in the dip is indefinitely known. Whether it actually renders the dip more efficacious is uncertain. It does, however, give body to the dip, and also serves the useful purpose of rendering the appearance and odor of the dip distinctive.

## DETAILS OF THE EXPERIMENTS.

### ARSENIC, SODA, AND PINE-TAR DIPS.

*Experiment No. 1.*

Twelve head of cattle, most of them moderately or heavily infested with ticks, were dipped October 13, 1907, near Quanah, Tex., in an arsenic, soda, pine-tar dip containing an equivalent of 0.204 per cent arsenic trioxid.[2] The dip was prepared from 20 pounds of commercial arsenic (96.18 per cent arsenic trioxid[2]), 60 pounds of sal soda, 2 gallons of pine tar, and 1,075 gallons of water. The quantity of water was determined from arithmetical calculations based upon measurements of the dimensions of the vat. The vat was about 20 feet in length at the surface of the dip, and the cattle when dipped were immersed from 5 to 10 seconds.

[1] Bureau of Animal Industry Circular 182.

[2] Analysis made in Biochemic Division.

The cattle suffered no evident injury to the skin as a result of dipping. Seven days after dipping they were nearly free from ticks, the ticks present being partially grown females, males, and nymphs. Of six engorged ticks which dropped from the cattle immediately after dipping, 4 died without depositing eggs, the other 2 depositing a few eggs, none of which hatched. Two days after dipping 14 engorged ticks were collected, 5 of which died without depositing eggs. The other 9 deposited a few eggs, none of which hatched. Eight engorged ticks collected October 12 from undipped cattle, and kept under the same conditions as those from the dipped cattle, all deposited a normal number of eggs, nearly all of which hatched. Four nymphs were collected two days after dipping. One afterwards molted, 1 died in course of molting, and 2 failed to molt. Seven days after dipping 13 nymphs were collected. One of these afterwards molted, and 12 failed to molt. Fourteen nymphs were collected from an undipped cow October 15 and kept under the same conditions as those from the dipped cattle. Ten of these afterwards molted, 1 died while molting, and 3 failed to molt.

*Experiment No. 1a.*

October 16, three days after the first dipping, a heavily infested cow was redipped, after the addition of 4 pounds of arsenic and 12 pounds of soda, previously boiled together, to the dip already in the vat. No analysis was made of this strengthened dip, but the amount of arsenic may be estimated as equivalent to about 0.24 per cent arsenic trioxid.

October 20, four days after the second dipping and seven days after the first dipping, there was no apparent injury to the skin. Nearly all the ticks were dead. Those remaining alive were females one-half to fully grown, most of them showing distinct evidences of having been injured by the dip. Twenty-five engorged ticks were collected from the cow in this experiment four days after the second dipping; 19 of these died within 24 hours; 2 of the remaining 6 afterward deposited a few eggs, none of which hatched. The other 4 died without depositing eggs. Fourteen engorged ticks collected from undipped cattle October 22 and kept under the same conditions as those from the dipped cow deposited numerous eggs, most of which hatched. Another lot of 6 engorged ticks collected on the same date from undipped cattle deposited about 1,000 eggs, about 100 of which hatched.

*Experiment No. 2.*

Two cattle heavily infested with ticks were sprayed in a spraying machine October 22, 1907, near Vernon, Tex., with an arsenic, soda, and pine-tar dip containing an equivalent of 0.172 per cent arsenic trioxid.[1] The dip was prepared from 10 pounds of commercial arsenic (99.56 per cent arsenic trioxid [1]), 24 pounds of sal soda, 1 gallon of

[1] Analysis made in Biochemic Division.

pine tar, and 500 gallons of water (measured in barrels). The cattle were held in the spraying machine for about 10 seconds. Owing to the faulty working of the machine, the application of the dip was not as thorough as it might have been had the machine worked properly.

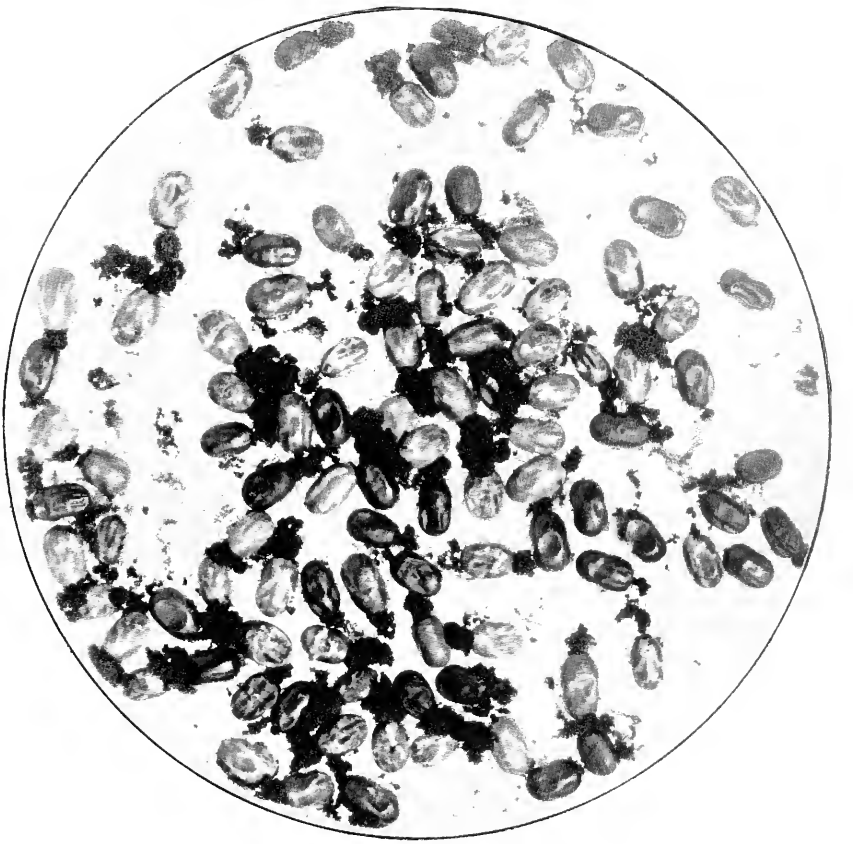
The skin injury as a result of spraying was very slight, and the evidences of injury had practically disappeared eight days after the treatment. Five days after spraying the skin of one of the animals was somewhat thickened between the hind legs and on the neck where the ticks had been numerous, and the skin on the neck of the other animal where the ticks had been particularly numerous was very slightly thickened and cracked. The cattle were nearly free from ticks eight days after spraying, the ticks present being partially grown females, males, and nymphs. Eight engorged ticks were collected from the cattle 16 hours after spraying. One of these died without depositing eggs; the other 7 laid relatively few eggs, none of which hatched. Of 5 engorged ticks collected five days after spraying, 4 died without depositing eggs; the other one laid about 200 eggs, none of which hatched. Fourteen engorged ticks collected October 22 from untreated cattle and kept under the same conditions as those from the sprayed cattle deposited numerous eggs, most of which hatched, and another lot of 6 engorged ticks collected on the same date from untreated cattle deposited about 1,000 eggs, about 100 of which hatched. Seven nymphs collected 16 hours after spraying failed to molt. Sixty-nine nymphs collected five days after spraying failed to molt. Seven nymphs collected eight days after spraying failed to molt. Twenty-five nymphs were removed from untreated cattle October 22 and were afterwards kept under the same conditions as those from the sprayed cattle. All but 4 of these molted.

*Experiment No. 3.*

Three cattle heavily infested with ticks and two cattle lightly infested were sprayed July 11, 1908, near Purcell, Okla., with an arsenic, sal soda, and pine-tar dip containing an equivalent of not more than 0.217 per cent arsenic trioxid. The dip was prepared from 3 pounds of commercial arsenic (99.05 per cent arsenic trioxid [1]), 15 pounds of sal soda, 0.3 gallon of pine tar, and 165 gallons of water. The same spraying machine was used that was used in Experiment No. 2. The cattle were not held in the machine, but were allowed to pass through as rapidly as they would.

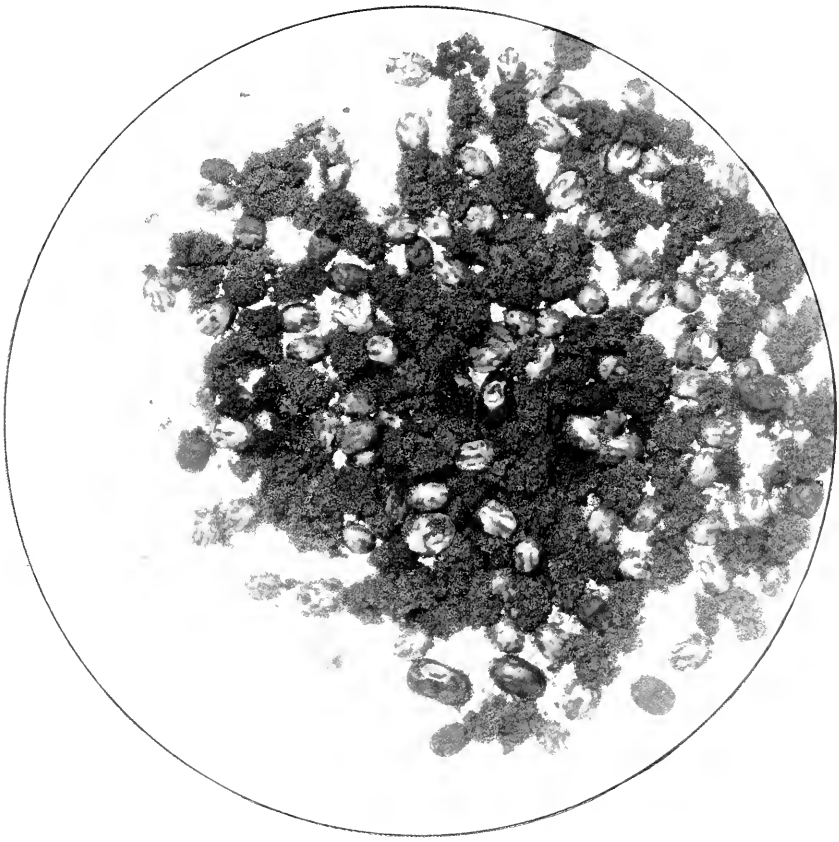
The skin of these cattle was only very slightly injured. Five days after treatment 3 of the cattle were nearly free from ticks; the other 2 could not be found on this date. The live ticks present were 2 engorged females, a few partially grown females, 1 male, and a considerable number of nymphs, which were apparently still alive.

[1] Analysis made in Biochemic Division.



Dipped Ticks.

Experiment No. 4. One hundred and twenty-three engorged female ticks after dipping in an arsenical solution containing an equivalent of less than 0.22 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 23.4 milligrams, and none of them hatched. Two-thirds natural size; from a photograph taken 24 days after dipping. Compare Plate II, showing untreated ticks collected on the same date as those shown in this plate.



Undipped Ticks.

Experiment No. 4. One hundred and five engorged female ticks collected on the same date as those shown in Plate I, and kept under the same conditions, but not dipped. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 127.5 milligrams, and practically all of them hatched. Two-thirds natural size; from a photograph taken on the same date as that of the ticks shown in Plate I.

Fifteen engorged females were removed from the cattle immediately after spraying. All of these died without depositing eggs.

For comparison it may be noted, in the absence of any data as to engorged ticks from untreated cattle on July 11, that engorged ticks (number not recorded) collected July 11 from cattle sprayed July 8 with an emulsion of crude petroleum and liquor cresolis compositus containing about 5 per cent crude petroleum and about 1 per cent cresylic acid, deposited a normal number of eggs, many of which hatched. These ticks were kept, after their removal from the cattle, under the same conditions as those from the cattle sprayed with the arsenical dip. Six nymphs were collected immediately after spraying from the cattle sprayed with arsenical dip, and 2 of these molted. Four nymphs were collected on the same date from the cattle sprayed three days before with the oil and cresol emulsion, and were kept after collection under the same conditions as those from the cattle sprayed with the arsenical dip; all but one of them molted.

*Experiment No. 4.*

August 7, 1908, 228 fully engorged ticks were collected from some infested cattle at the Bureau Experiment Station, Bethesda, Md. On August 8, 123 of these ticks were immersed in an arsenical solution containing an equivalent of not more than 0.213 per cent arsenic trioxid. They remained in the solution two minutes, were then removed and dried by means of filter paper, after which they were placed in a large Petri dish under a bell jar under which was also placed an open vessel of water. The arsenical solution was prepared from 1 gram of arsenic trioxid, 3 grams of sodium carbonate, and 465 c. c. of water. No pine tar was added to the solution. Twenty-two of the ticks died without depositing eggs. The remainder deposited eggs whose aggregate weight equaled 2.876 grams. Oviposition was completed September 1 (see Pl. I, from a photograph taken on this date). None of the eggs hatched.

August 8 the remainder of the ticks collected the day before, 105 in number, were placed in a Petri dish under the same bell jar as those which were immersed in arsenical solution and kept thereafter under the same conditions as the latter. All of the untreated ticks deposited eggs whose aggregate weight amounted to 13.394 grams, nearly 5 times the weight of the eggs from the dipped ticks.[1] Oviposition was completed September 1 (see Pl. II, from a photograph taken on this date). Practically all of the eggs from the untreated ticks afterwards hatched.

[1] It is to be noted here and hereafter in this paper that when a comparison by weight is made between the eggs laid by ticks that have been dipped and the eggs in the corresponding control lot, the difference is somewhat emphasized, due to the fact that the eggs from dipped ticks commonly become more or less shriveled, and hence weigh somewhat less than the same number of normal eggs.

*Experiment No. 5.*

During several weeks in the late summer and early fall of the year 1908, larval ticks were applied every other day to three calves at the Bureau Experiment Station, Bethesda, Md. On October 12 numerous ticks of all ages, from newly attached larvæ to fully engorged females, were present on each of these animals. An arsenic, sal soda, and pine-tar dip was prepared which contained an equivalent of 0.16 per cent arsenic trioxid.[1] On the above-mentioned date one of the calves (No. 582) was dipped in the arsenical dip and was kept in the bath two minutes. After dipping this calf was placed in a noninfested pen. Beginning immediately after dipping, all female ticks, so far as possible, were collected every day as they reached the stage of full engorgement. These ticks were brought to the laboratory and kept in Petri dishes. All but a very few of the ticks which matured were collected. Those which matured during the night of course escaped, except those found in the morning crawling on the floor of the pen.

During the first week after dipping, October 12 to 18, inclusive, 1,340 engorged ticks were collected from calf No. 582. The eggs of 291 of these ticks, comprising some individuals from each day's collection, amounted in weight to 5.57 + grams, an average of 0.019 gram per tick. Applying this average to the entire 1,340 ticks, the total weight of eggs may be assumed to be 25.46 grams. By calculation from the records which were kept of the percentage of eggs hatching from the ticks of each day's collection, the eggs which hatched were found to correspond to a weight of 0.178 + gram, or 0.7 per cent of all the eggs deposited by the ticks maturing the first week after dipping, which corresponds to an average of 0.000133 gram per tick. Subsequent to October 18, ticks continued to mature on calf No. 582 until November 9, four weeks after dipping, the total number maturing during this time being 67.

Calf No. 583 was dipped October 12 in the arsenic, soda, and pine-tar dip after 0.5 per cent (by weight) glycerin was added. The period of immersion in the bath was 1½ minutes. After dipping, the calf was placed in a noninfested pen. The same procedure with regard to the collection of engorged ticks was followed as in the case of the other calf. During the first week after dipping, from October 12 to 18, inclusive, 1,907 engorged ticks were collected from calf No. 583, and the eggs of 599 of these ticks amounted in weight to 10.2 + grams, an average of 0.017 gram per tick. Assuming that each of the entire number (1,907) collected averaged the same amount of eggs deposited, the entire weight of eggs may be estimated at 32.4 + grams. The number hatching, as calculated from the records kept of the per-

[1] Analysis made in Biochemic Division.

centage which hatched from the ticks of each day's collection, corresponds to a weight of 0.325 gram, which is 1 per cent of the total quantity of eggs laid, or an average of 0.00017 gram per tick. The last tick to mature on calf No. 583 was collected on November 7, up to which time and subsequent to October 18, 37 female ticks reached the engorged condition.

Calf No. 584, the undipped animal, was put in a noninfested pen October 12 and no more larvæ placed on it. The ticks which matured were collected every day, and some of these were placed in Petri dishes and kept under the same conditions as the ticks from the 2 dipped animals. October 12 to 18, inclusive, the number of engorged ticks collected from calf No. 584, of which a record was kept, was 968. The weight of the eggs deposited by 358 of these was 25.54+ grams, an average of 0.071 gram per tick. This average is about four times greater than the averages of the ticks from the 2 dipped calves. On the basis of an average of 0.071 gram of eggs per tick the total number of eggs deposited by the recorded ticks collected from calf No. 584 October 12 to 18 may be estimated as corresponding to a weight of 68.7+ grams. The number which hatched, as calculated from the records kept of the percentage which hatched from the ticks of each day's collection, corresponds to a weight of 55.59 grams, which is 80 per cent of the weight of the entire number of eggs deposited, or 0.0568 gram per tick.

Assuming 0.04 milligram to be the average weight of a single egg, the average number of larvæ produced by each tick maturing on calf No. 584, the undipped animal, as calculated from the foregoing data, was 1,400, whereas the number of larvæ produced by the ticks maturing on the other calves during the first week after dipping averaged, as determined by a similar calculation, only 3.2 for each tick maturing on calf No. 582 and 4.2 for each tick maturing on calf No. 583. Ticks continued to mature on calf No. 584 until November 18, and during the period from October 19 to November 9 (the latter date being the last day on which any ticks matured on either of the dipped animals) 1,029 ticks were recorded as maturing on this animal, in comparison with which it should be noted that only 67 and 37 ticks, respectively, matured on the 2 dipped cattle subsequent to October 18.

From the foregoing it is evident that the 2 dipped calves became almost free from ticks within a week after dipping, only 67 in one case and 37 in the other, which afterwards matured, being present at the end of this time, a marked contrast to the fact that more than 1,029 ticks that afterwards matured were still present on the undipped calf a week after removal from further infestation.

No injury to the skin from dipping was noted other than a very slight dandruff-like exfoliation. The addition of the glycerin to the

dip in which the second calf was dipped had no apparent effect on the action of the dip.

*Experiment No. 6.*

On August 13, 1909, a calf which had been artificially infested with ticks, and which at the time of dipping harbored ticks in all stages of development, was dipped at the Bureau Experiment Station in an arsenic, sal soda, and pine-tar dip containing an equivalent of 0.215 per cent arsenic trioxid.[1] The dip was prepared from 7 pounds of arsenic trioxid, 21 pounds of sodium carbonate (crystallized), 0.7 gallon of pine tar, and about 350 gallons of water. The calf remained in the bath two minutes. After dipping, the calf was kept in a tick-infested pen until August 20, seven days after the first dipping, when it was redipped in the dip which had been left in the vat since the first dipping. The calf was kept in the bath two minutes at the second dipping, and then removed to a non-infested pen. Beginning immediately after the first dipping the female ticks were collected as they reached the engorged condition.

The skin of the calf was very slightly affected by the dipping, became somewhat thickened in places on the neck and thighs, and some exfoliation occurred. When the animal was discharged from the experiment September 9 the skin was in excellent condition, soft, pliable, and very sleek.

Five days after the first dipping a few newly molted adult ticks and a few partially engorged females were found to be alive. The latter were abnormally swollen as a result of arsenical poisoning. Nymphs apparently alive were rather numerous. Seven days after the first dipping most of these were certainly dead. A few newly molted adults were found to be alive, and partially grown females, abnormally swollen, were still present. No live larvæ were found on either the fifth or seventh day. Eight days after the first dipping no live ticks in any stage of development were found, nor were any found subsequently.

August 13, immediately after dipping, 57 engorged and nearly engorged female ticks were collected from the calf, all but 18 of which died without depositing eggs. These 18 ticks deposited eggs whose aggregate weight amounted to 0.077 gram, and none of these hatched. (See Pl. III, fig. 1, from a photograph taken Aug. 31.) Later in the day, August 13, 27 engorged females were collected, 17 of which died without depositing eggs. The other 10 deposited eggs aggregating 0.1008 gram in weight, none of which hatched.

In comparison note that 17 engorged females collected August 13 from an undipped calf and kept under the same conditions as those from the dipped calf all deposited eggs weighing 0.8953 gram, 97

[1] Analysis made in Biochemic Division.

FIG. 1.—DIPPED TICKS.

Experiment No. 6. Fifty-seven engorged and nearly engorged female ticks collected from a calf immediately after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 1.3 milligrams, and none of them hatched. Natural size; from a photograph taken 18 days after collection.

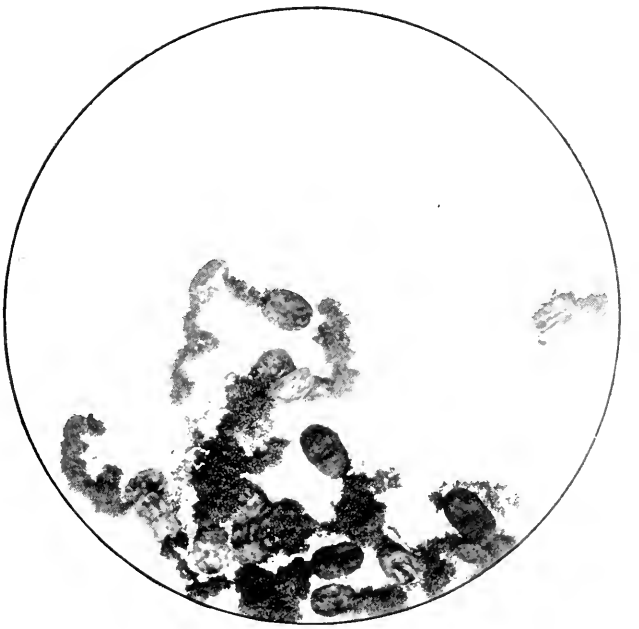


FIG. 2.—UNDIPPED TICKS.

Experiment No. 6. Seventeen engorged female ticks collected from an undipped calf on the same date as those shown in Fig. 1, and kept under the same conditions. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 52.7 milligrams, and 97 per cent of them hatched. Natural size; from a photograph taken 18 days after collection.

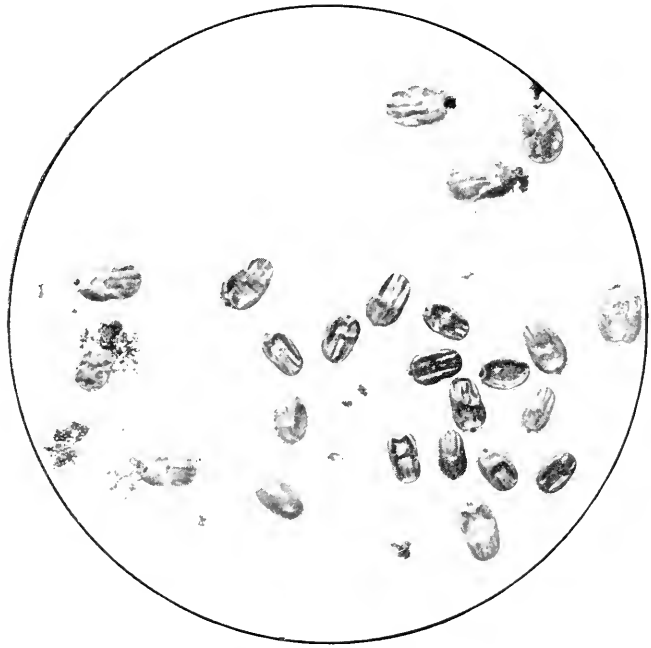


FIG. 1.—DIPPED TICKS.

Experiment No. 6. Seven fully engorged and seventeen partially engorged female ticks collected from a calf the next day after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 2.1 milligrams, and none of them hatched. Natural size; from a photograph taken 17 days after collection.

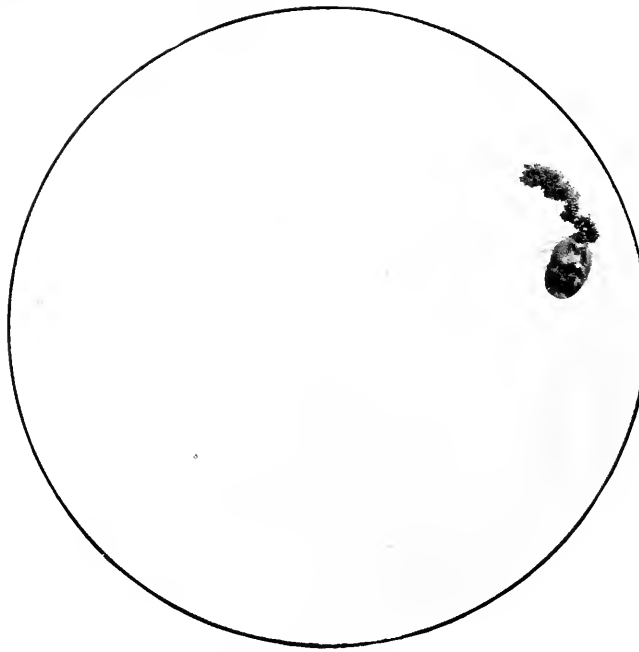


FIG. 2.—UNDIPPED TICK.

Experiment No. 6. Collected from an undipped calf one day earlier than those shown in Fig. 1, and kept under the same conditions. The weight of eggs deposited by this tick was 42.6 milligrams, and 40 per cent of them hatched. Natural size; from a photograph taken 18 days after collection.

per cent of which hatched. (See Pl. III, fig. 2, from a photograph taken Aug. 31.) Note also that one engorged female collected August 13 from an undipped calf and kept under the same conditions as the ticks from the dipped calf deposited eggs weighing 0.0426 gram, 40 per cent of which hatched. (See Pl. IV, fig. 2, from a photograph taken Aug. 31.)

August 14, 24 ticks were collected, 7 of which were fully engorged, the others partially engorged. Five of these laid eggs weighing 0.0512 gram. The others died without laying eggs. None of the eggs hatched. (See Pl. IV, fig. 1, from a photograph taken Aug. 31.) No ticks were collected on this date from undipped cattle, but it may be noted that ticks, already referred to, which were collected from undipped cattle the day before and were kept under the same conditions as those from the dipped calf deposited numerous eggs, a large proportion of which hatched. (See Pl. IV, fig. 2, and Pl. III, fig. 2, from photographs taken Aug. 31.)

August 15, 17 ticks (7 fully engorged and 10 partially engorged) were collected. Thirteen of these died without laying eggs. The other 4 laid eggs aggregating 0.05 gram in weight, none of which hatched. (See Pl. V, fig. 1, from a photograph taken Aug. 31.) No ticks were collected from undipped cattle on this date, but the lot of ticks just discussed may be compared with a lot of 8 females (5 fully engorged and 3 partially engorged) collected from an undipped calf the following day, August 16. These were kept under the same conditions as the ticks from the dipped calf, and all of them deposited eggs aggregating 0.4686 gram in weight, 99 per cent of which hatched. (See Pl. V, fig. 2, from a photograph taken Aug. 31.)

August 16, 9 ticks (5 fully engorged and 4 nearly engorged) were collected, 2 of which died without laying eggs. The other 7 laid eggs aggregating 0.1713 gram in weight, none of which hatched.

In comparison note that 8 ticks (5 fully engorged and 3 partially engorged) collected from an undipped calf August 16 and kept under the same conditions as the ticks from the dipped calf, all deposited eggs weighing 0.4686 gram, 99 per cent of which hatched.

August 17, four days after the first dipping and the last day on which any ticks matured on the calf in this experiment, 1 engorged female was collected. This tick deposited eggs weighing 0.056 gram, and 50 per cent of them hatched. A tick collected from an undipped calf on the same date, and kept under the same conditions as the ticks from the dipped calf, deposited eggs weighing 0.0715 gram, 98 per cent of which hatched.

*Experiment No. 7.*

August 17, 1909, 15 engorged ticks collected the day before from undipped cattle at the Bureau Experiment Station were immersed in some of the dip used in Experiment No. 6, which contained an equivalent of 0.215 per cent arsenic trioxid. The ticks remained in the dip two minutes, were then removed, dried on filter paper, placed in a Petri dish, and kept under observation in the laboratory. Two of these survived until August 30, but none laid any eggs. Eight engorged ticks, which were collected on the same day as the ticks just referred to and kept under the same conditions except that they were not dipped, all deposited eggs whose aggregate weight equaled 0.4686 gram. Ninety-nine per cent of these eggs hatched.

August 27, another lot of ticks, consisting of 51 engorged females collected August 25, were dipped in some of the same dip and were handled and kept under the same conditions as those discussed in the preceding paragraph. All of these died without laying eggs. (See Pl. VI, fig. 1, from a photograph taken Aug. 31.) Another lot of 40 females, collected August 25 and kept under the same conditions except that they were not dipped, all deposited eggs whose aggregate weight amounted to 2.1371 grams, and 60 per cent of these eggs hatched. (See Pl. VI, fig. 2, from a photograph taken Aug. 31, before oviposition was entirely completed.)

*Experiment No. 8.*

On August 26, 1909, a tick-infested calf was dipped in the arsenical dip used in Experiment No. 6, which had remained in the vat at the Bureau Experiment Station since August 13. This dip originally contained an equivalent of 0.215 per cent arsenic trioxid, but analysis of a sample taken September 2 showed an equivalent of 0.234 per cent arsenic trioxid. It is assumed that the dip had meanwhile lost sufficient water by evaporation to cause this increase in the percentage of arsenic. When used August 26 the dip therefore contained an equivalent of between 0.215 and 0.234 per cent arsenic trioxid.

The calf used in this experiment had been artificially infested with ticks by applying larvæ every other day for several weeks prior to dipping. When the animal was dipped numerous ticks in all stages of development were present. The period of immersion in the bath was two minutes. After dipping, the calf was put into a tick-infested inclosure, and larval ticks were applied every other day until September 2, when a second dipping was given. Before the animal was dipped the second time about 50 gallons of water were added to the dip in the vat. Analysis of a sample taken from the vat after the addition of the water showed that it contained an equivalent of

Fig. 1.—Dipped Ticks.

Experiment No. 6. Seven fully engorged and ten partially engorged female ticks collected from a calf two days after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 3 milligrams, and none of them hatched. Natural size; from a photograph taken 16 days after collection.

Fig. 2.—Undipped Ticks.

Experiment No. 6. Five fully engorged and three partially engorged female ticks collected from an undipped calf one day later than those shown in Fig. 1, and kept under the same conditions. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 58.6 milligrams, and 99 per cent of them hatched. Natural size; from a photograph taken 15 days after collection.

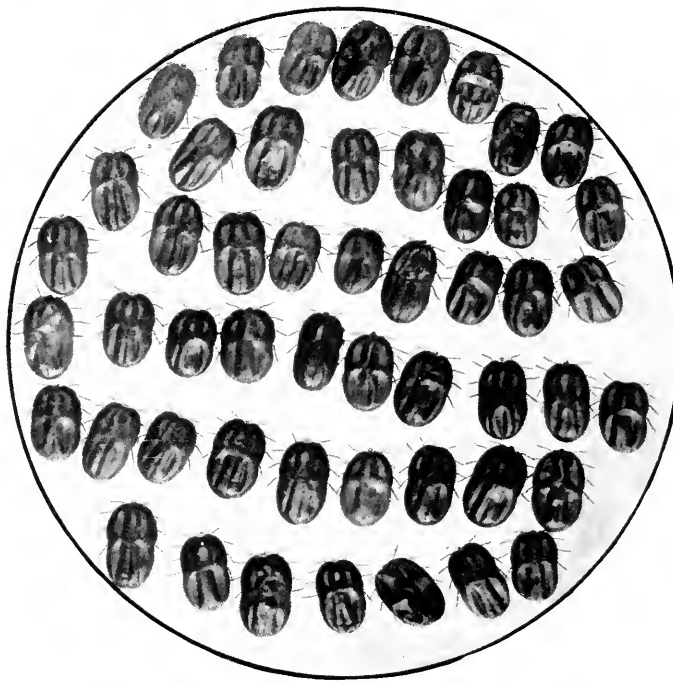


FIG. 1.—DIPPED TICKS.

Experiment No. 7. Fifty-one engorged female ticks after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. All of them died without depositing eggs. Natural size; from a photograph taken 4 days after dipping.

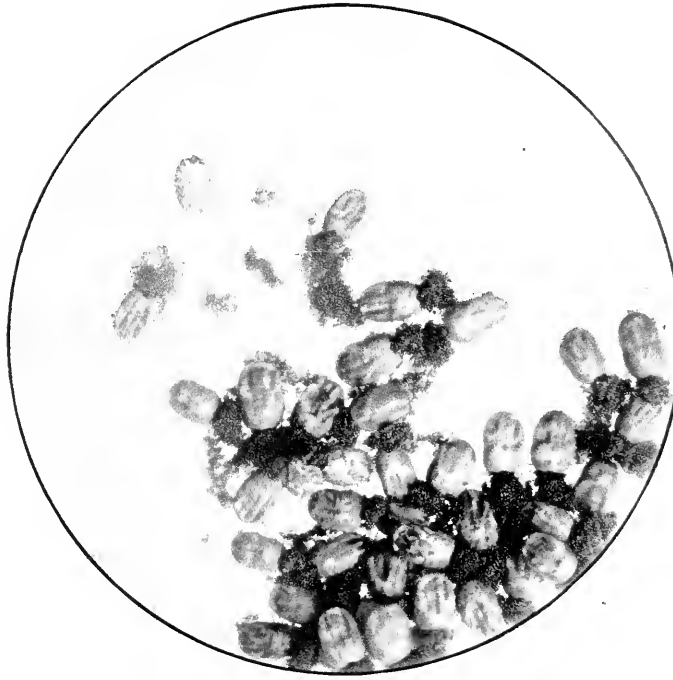


FIG. 2.—UNDIPPED TICKS.

Experiment No. 7. Forty engorged female ticks collected from an undipped calf on the same date as those shown in Fig. 1, and kept under the same conditions, but not dipped. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 53.4 milligrams, and 69 per cent of them hatched. Natural size; from a photograph taken on the same date as that of the ticks shown in Fig. 1.

0.196 per cent arsenic trioxid. The period of immersion at the second dipping was two minutes. After this dipping the calf was removed to a noninfested yard. August 28, two days after the first dipping, no injury to the skin was yet apparent. September 2 the skin was slightly sore on the escutcheon and on the vulva, near the tail. There was a slight exfoliation on the inner side of the forelegs. On September 9, seven days after the second dipping, there was noted a very slight exfoliation, and the skin was very slightly irritated on escutcheon, inguinal region, axillæ, inner side of forelegs, and around anus. A few days later all signs of skin injury had disappeared.

August 28, two days after the first dipping, a considerable number of adult ticks in various stages of growth were alive, many of them, however, evidently affected by the arsenic. Some nymphs were apparently alive. No ticks matured subsequent to August 29, three days after the first dipping. September 2 no live ticks were found, except some nymphs which were apparently alive. September 9, one week after the second dipping, the calf was entirely free from ticks.

August 26, immediately after the first dipping, 46 engorged female ticks were collected from the calf. All of these but one died without laying eggs. This one deposited about 30 eggs, none of which hatched. Later on the same day 6 engorged females were collected, 3 of which died without laying eggs. The other 3 laid eggs weighing 0.0874 gram, none of which hatched.

In comparison with the above it may be noted that 40 engorged females collected from an undipped calf August 25, and kept under the same conditions as those from the dipped calf, all deposited eggs which weighed in the aggregate 2.1371 grams, 60 per cent of which hatched.

August 27, 32 engorged females were collected from the dipped calf, all but 8 of which died without laying eggs. These 8 deposited eggs weighing 0.0407 gram, none of which hatched.

August 28, 6 engorged females were collected, 4 of which deposited eggs weighing 0.1034 gram. None of these hatched. The other 2 died without depositing eggs.

August 29, three days after the first dipping, the last ticks to mature were collected. These were 9 in number. All but 1 of these died without ovipositing. This one laid about 75 eggs, none of which hatched.

No ticks with which the above may be compared were collected from undipped cattle between August 25 and September 7. The data previously given relative to 40 ticks collected on August 25 from an undipped calf should, however, be noted in comparison with the data relative to the ticks maturing on the dipped calf, and

it may also be noted that 5 engorged females collected September 7 from undipped cattle deposited numerous eggs, 98 per cent of which hatched.

*Experiment No. 9.*

Beginning September 8, 1909, 3 calves, Nos. 725, 731, and 735, were artificially infested with ticks at the Bureau Experiment Station by applying larvæ every other day. October 22 ticks in all stages of development were present, but none of the 3 calves exhibited more than a moderate degree of infestation. A greater number of ticks in the various younger stages than in the later adult stage were present. The 3 calves were dipped October 22 in an arsenical dip freshly prepared from 7 pounds of arsenic trioxid, 8 pounds of anhydrous sodium carbonate, 0.7 gallon of pine tar, and 350 gallons of water. The dip contained an equivalent of 0.225 per cent arsenic trioxid.[1]

Calf No. 725 was immersed in the bath 2 minutes, calf No. 731 1 minute, and calf No. 735 30 seconds. After dipping the 3 calves were removed to a tick-free yard.

October 30, eight days after dipping, no skin injury was apparent. November 6 a dandruff-like scurf was noted on various parts of the body, but a similar condition was noted on the neck and dewlap of another calf which had never been dipped. In this experiment the skin injury may therefore be put down as so slight as to be scarcely if at all perceptible.

October 30, eight days after dipping, a very few live partially grown adults and a very few nymphs apparently alive were found on calf No. 725 (dipped 2 minutes); a few live, partially grown adults and a few nymphs apparently alive on No. 731 (dipped 1 minute); and on No. 735 (dipped 30 seconds) it was noted that partially grown females were present which were abnormally swollen from arsenical poisoning. No ticks matured on any of the three animals subsequent to October 26, four days after dipping. November 6, two weeks after dipping, the three calves when finally examined were found to be entirely free from ticks.

Twenty engorged females were removed from No. 725, October 22, immediately after dipping, 3 of which died without depositing eggs. The other 17 deposited eggs amounting in weight to 0.3273 gram, none of which hatched. From No. 731, immediately after dipping, October 22, 6 engorged females were removed, 2 of which survived to deposit eggs, which amounted in weight to 0.0262 gram. None of these hatched. From No. 735, October 22, immediately after dipping, 14 females were removed, all but 1 of which were fully engorged.

[1] Analysis made in Biochemic Division.

Eleven of these survived to deposit eggs, whose weight amounted to 0.1933 gram. None of these hatched. In comparison it may be noted that 6 engorged females, removed from an undipped calf October 22 and kept under the same conditions as those from the dipped cattle, all deposited eggs which aggregated 0.2599 gram in weight and that 25 per cent of these hatched.

October 23, 15 engorged ticks were collected from calves Nos. 731 and 735. Twelve of these deposited eggs weighing 0.335 gram, none of which hatched. The other 3 died without ovipositing. Ten engorged females were collected from No. 725 on October 23, 4 of which survived to deposit eggs, the other 6 dying without ovipositing. The eggs which were laid aggregated 0.0515 gram in weight, and none of them hatched. Twelve engorged females collected from an undipped calf October 23 and kept under the same conditions as those from the dipped cattle all deposited eggs, which aggregated 0.4422 gram in weight. Ten per cent of these hatched.

October 24, 3 engorged females were collected from No. 725. All of these deposited eggs which amounted in weight to 0.0574 gram, none of them hatching. From No. 731 on October 24 were collected 1 fully engorged and 3 nearly engorged females. Two of these survived to deposit eggs which amounted in weight to 0.0335 gram. None of the eggs hatched. Twenty-one fully engorged and 8 nearly engorged female ticks were collected from No. 735 on October 24. Seventeen of these survived to lay eggs, the other 12 dying without ovipositing. The eggs laid amounted in weight to 0.2458 gram, and none of them hatched.

In comparison with the foregoing it may be noted that 13 females collected from an undipped calf on October 24 and kept under the same conditions as those from the dipped cattle all deposited eggs which amounted in weight to 1.0794 grams. One per cent of these hatched.

October 25, 4 engorged females were collected from No. 725, 1 of which survived to lay eggs, which weighed 0.0255 gram. None of these hatched. One small engorged female was collected from No. 731 on October 25. This tick died after depositing a very few eggs, none of which hatched. Eight fully engorged and 3 nearly engorged females were collected from No. 735 on October 25. Three of these ticks survived to lay eggs, which amounted in weight to 0.0372 gram. None of the eggs hatched. It may be noted in comparison with the foregoing that of 18 engorged females collected October 25 from an undipped calf and kept under the same conditions as those from the dipped cattle, 17 deposited eggs which amounted in weight to 0.5333 gram. Two per cent of these hatched.

October 26, 1 engorged female was collected from No. 731. This tick deposited eggs weighing 0.0397 gram, none of which hatched.

On the same date 4 females nearly engorged were collected from No. 735, all of which died without depositing eggs. Of 7 engorged females collected from an undipped calf October 26 and kept under the same conditions as those from the dipped cattle, all deposited eggs. These eggs amounted in weight to 0.3705 gram and 1 per cent of them hatched.

No ticks matured on calf No. 725 subsequent to October 25, three days after dipping, and none matured on Nos. 731 and 735 subsequent to October 26, four days after dipping.

Owing to the low relative humidity to which the eggs of the ticks were subjected in this experiment, and the consequent small percentage of eggs hatching in the case of the ticks from undipped cattle used for comparison, the failure of eggs deposited by ticks from the dipped cattle to hatch is less striking than in the other experiments.

*Experiment No. 10.*

November 10, 1909, eleven 3-year-old steers and one 4-year-old steer were dipped at Benjamin, Tex., in an arsenic, sal soda, and pine-tar dip containing an equivalent of 0.22 per cent arsenic trioxid.[1] The dip was prepared from 70 pounds of commercial arsenic (99.2 per cent arsenic trioxid [1]), 180 pounds of sal soda, 7 gallons of pine tar, and about 3,500 gallons of water. The vat used measured 35 feet 8 inches in length at the surface of the dip. The cattle in entering slipped down a slide board and, plunging into the bath, were totally immersed for a moment, after which they swam through the vat to the other end, where they left the bath by walking up an incline, which led to the draining pen. Each animal was in the bath from 10 to 12 seconds. The cattle were ordinary grass-fed steers in rather poor flesh, but strong and healthy. At the time the experiment was begun they all showed a moderate infestation with ticks in all stages of development.

The cattle were dipped on the afternoon of November 10. They remained in the stockyards overnight, and the following morning were driven about 5 miles to a small pasture, said to be badly infested with ticks, where they remained until the morning of November 17.

November 14, four days after dipping, each of the 12 cattle was examined. For this purpose they were placed one by one in a chute at the ranch where the cattle were pastured during the interval between dippings. The unusual gentleness of the cattle greatly facilitated this and the other examinations and handling to which they were subjected during the experiment. On animals Nos. 1, 4, and 6 a few live, fully engorged, partially engorged, and newly molted adult female ticks were found. All except the fully engorged

[1] Analysis made in Biochemic Division.

ticks showed distinct evidence of the injurious effects of the dip; that is, they were unnaturally swollen and in some instances abnormal in color. On No. 12 slight exfoliation of the skin was evident at the root of the tail and on the escutcheon. One live engorged female and a few live ticks in stages just prior to and just after the second molt were found. Nos. 2 and 8 showed slight exfoliation of the skin, and harbored live ticks in stages just prior to and after the second molt. On Nos. 3 and 7 live, newly molted adult ticks were found, together with a few partially engorged females which were abnormally swollen and in a dying condition. No. 10 had a few live ticks partially engorged, and showed a slight exfoliation and tenderness of the skin on the escutcheon where the ticks had been numerous. The skin on the dewlap was slightly thickened and sensitive. On No. 5 there were a few live, newly molted adult ticks and the skin of the animal was very slightly affected. On No. 9 there was 1 fully engorged live tick, a number partially engorged, evidently poisoned by the dip, and a few live young adults. The skin of this animal showed a very slight exfoliation. On No. 11 there were a few live ticks, some of them young adults and some nearly engorged; all more or less affected by the dip. The skin showed scarcely any evidence of having been affected by the dip.

November 17, one week after the first dipping, the cattle were driven back to the stockyards at Benjamin, where they were again examined. For this purpose the cattle were placed in the chute leading to the dipping vat. The cattle that exhibited signs of skin injury (i. e., slight irritation and exfoliation) November 14 showed similar signs at this examination. The animals presented the appearance of having gained in weight since dipping. No fully engorged females were found alive on these cattle November 17. On No. 1, some half-grown adult ticks were found to be alive, and there were some nymphs apparently alive. On No. 3 the only live ticks found were a few partially grown adults badly affected by arsenical poisoning. On No. 4 there were a few partially grown females alive but affected by the dip, and a few nymphs apparently alive. On No. 5, 1 recently molted female, and 1 partially grown female, both affected by the dip, were found alive, and there were present also some nymphs possibly alive. On No. 6, 1 newly molted male was found alive, and 1 nymph apparently alive. On No. 7 a small partially grown live female and a nymph apparently alive were found. One newly molted female affected by the dip was all that was found alive on No. 8. On No. 9 some newly molted adults were found alive and a very few nymphs apparently alive. No. 10 had a few partially grown female ticks, which were badly affected by the dip. On No. 11 only 1 tick was found alive, a female two-thirds grown, badly affected by the dip. No ticks were found on No. 12.

November 17, between 10 and 3 o'clock, the cattle were redipped in the dip remaining in the vat from the first dipping. During the dipping one of the animals became lodged in the vat in consequence of which he and 5 others remained in the bath nearly 1 minute. The remaining 6 were in the vat from 10 to 12 seconds each.

At 6 o'clock November 17 the 12 cattle were loaded into a stock car, partitioned in such a manner that they were confined to a little more than one-half the interior space of the car. This car was one which had been disinfected at Kansas City October 21 under supervision of a bureau inspector. It was further disinfected, before loading the cattle, by cleaning out all litter, sand, and dirt, and spraying with an arsenical solution of twice the strength of that used in dipping. At 8.20 p. m. the car of cattle left Benjamin in a local freight train, which arrived at Hamlin, Tex., about 55 miles distant, at 9.30 a. m. November 18. The cattle remained in the car at Hamlin and were brought back to Benjamin by a train which left Hamlin in the afternoon of November 18, and arrived in Benjamin about 1.30 a. m. November 19. The total period the cattle spent on the car was therefore about 31 hours. They were supplied with hay during this time, but not watered. At Benjamin they were unloaded into a pen at the railroad stockyards which had been thoroughly cleaned and disinfected by scraping off the surface earth with a team and scraper, scraping away also the surface of the earth from a strip about 3 feet wide all around the outside of the fence, and by spraying all the woodwork inside and out with the double-strength arsenical solution as used in the disinfection of the car; finally the ground along the fence inside and outside was soaked with the double-strength arsenical solution. When seen on the morning of November 19 the cattle appeared to be in good condition. Beginning on this date they were fed Johnson-grass hay and a cottonseed product from a local mill.

On November 22, five days after the second dipping, the cattle were examined individually, each animal being tied for examination against the fence by means of ropes attached to the horns and one hind foot. Each animal showed evidence of slight epithelial desquamation—in some instances very slight—exhibited in the form of a dandruff in the hair on the neck and at the root of the tail. This was the only skin injury evident. No live ticks were found on any of the animals except No. 8. In the case of this animal there was a partially grown female on the escutcheon abnormally swollen from arsenical poisoning, and a nymph near the root of the tail which was doubtfully alive.

November 24 these two ticks were still present on No. 8. The nymph appeared slightly shriveled. November 25 the tick was gone

from the escutcheon and the nymph was still present but was dried and shriveled and certainly dead.

December 1, two weeks after the second dipping and three weeks after the first dipping, the cattle were again thoroughly examined as on November 22. More or less dandruff-like scurf from the skin was still present in the hair. The odor of pine tar, which was rather marked at previous examinations, had nearly disappeared. Many of the warbles with which all of the animals were more or less infested were examined and most of them proved to be alive. It is therefore evident that the arsenical dip has little effect on these parasites. No live ticks were found on any of the animals except one female near the root of the tail on No. 12. This tick was about one-sixth grown and was badly swollen from arsenical poisoning. Evidently this tick was one which had been overlooked at previous examinations. It no doubt passed through the first dipping and probably through the second as a nymph. During the examination it became detached, which prevented the possibility of determining its ultimate fate if it had remained on the animal. It was, however, so loosely attached that it could not have retained its hold much longer, and even if it had it was so badly affected by the dip that it is safe to say, in view of the history of ticks in a similar condition in other experiments, that it had no chance of ever reaching fertile maturity.

With reference to the weather conditions during the Benjamin experiments it may be noted (assuming that the records of the Weather Bureau station at Abilene, 80 miles distant, are applicable) that the only frost recorded was a killing frost on November 17, the day of the second dipping, and that this frost was the first of the season. The minimum temperature was 32° F., and this was recorded on November 17. The maximum temperature during the month of November was 84° F., recorded on the 5th, five days before the first dipping. The average daily maximum temperature during November was 71.6°, and the average daily minimum 50.1° F. Beginning November 10 the weather was clear on 5 days, cloudy on 5 days, and partly cloudy on 11 days. The average daily cloudiness for the month was 4.9 (Weather Bureau scale). On November 13, three days after the first dipping, 0.56 inch of rain fell between 11.10 a. m. and 2.40 p. m. On November 15 during the night 0.04 inch of rain fell. There was no further precipitation until November 28, when it began raining at 10.40 a. m., continuing until some time during the night, beginning again at 2.50 p. m., November 29, and ceasing at 9.40 p. m., the rainfall being 0.93 inch.

On the whole the weather was favorable to the experiment. No previous frost and an average temperature of 60° F. during the period between the two dippings when the cattle were on a pasture said to be tick-infested were circumstances favoring reinfection subsequent

to the first dipping. The occurrence of rain three and five days after the first dipping, if it had any influence on the results of the dipping, would have tended to diminish the effectiveness of the treatment by washing off some of the arsenic which it may be assumed was left on the bodies of the cattle after dipping.

The cattle were released and the Benjamin experiment was closed after the examination December 1.

*Experiment No. 11.*

September 23, 1910, 16 engorged female ticks collected September 20, 1910, from infested cattle at the Bureau Experiment Station, were immersed two minutes in an arsenical dip taken from the vat at the station, were dried on filter paper, then placed in a Petri dish and kept under observation in the laboratory. The dip was prepared June 23 from 7 pounds arsenic trioxid, 6½ pounds sodium carbonate (anhydrous), 0.7 gallon of pine tar, and 350 gallons of water, and remained in the vat all summer, cattle being dipped in it from time to time. Samples taken June 23 and July 14 showed an equivalent, respectively, of 0.217 per cent and 0.218 per cent arsenic trioxid in solution.[1] A sample taken September 15 showed in solution sodium arsenite equivalent to about 0.04 per cent arsenic trioxid, and total arsenic in solution equivalent to 0.217 per cent arsenic trioxid.[1] Therefore, in the dip when used in this experiment, although the total arsenic in solution was the same as when the dip was made, considerable oxidation[2] of the sodium arsenite had taken place.

A second lot of 16 engorged ticks collected September 20 from station cattle were dipped two minutes, September 23, in a freshly made arsenical dip (10 grams arsenic trioxid, 25 grams sodium carbonate (crystallized), 8 c. c. pine tar, and sufficient water to make 4,150 c. c.), which it may be assumed contained sodium arsenite equivalent to about 0.24 per cent arsenic trioxid.

Another lot of 16 engorged ticks collected September 20 were kept without dipping under conditions similar to the two lots which were dipped.

Two of the ticks in the lot dipped in the oxidized dip deposited a few eggs, none of which hatched. The other 14 died without ovipositing. One of the ticks dipped in the fresh dip deposited about a dozen eggs, none of which hatched. The others died without ovipositing. All of the 16 ticks which were not dipped deposited eggs, and of these 40 per cent hatched.

This experiment was repeated, using a second series of 2 lots of engorged ticks, 15 in each lot, collected September 22. One of these

[1] Analysis made in Biochemic Division.

[2] For a discussion of the oxidation of arsenical dips see a paper by Aubrey V. Fuller, of the Biochemic Division, entitled "The Spontaneous Oxidation of Arsenical Dipping Fluids," published as Bureau of Animal Industry Circular 182.

lots was dipped September 23 in the oxidized dip and the other in the freshly made dip. Nine of the ticks dipped in the oxidized dip deposited a few eggs, none of which hatched, the other 6 dying without ovipositing. All of the ticks dipped in the fresh dip died without ovipositing.

September 26, 66 engorged ticks were collected from undipped cattle, and on September 28 two lots of 22 each were dipped 2 minutes in the same dips that were used before. A third lot of 22 was kept under observation undipped. Three of the ticks dipped in the oxidized dip deposited a few eggs, none of which hatched, the remaining 19 dying without ovipositing. All of the 22 ticks dipped in the fresh dip died without ovipositing. Of the 22 undipped ticks, all but one deposited eggs, and 25 per cent of the eggs hatched.

In the case of a fourth series of ticks, 2 lots of 21 each were collected October 3. October 4, 1 lot was dipped in the arsenical dip which was freshly made September 23. The other lot was kept under observation undipped. Of the former lot, 3 deposited a few eggs, none of which hatched, the remaining 19 ticks dying without ovipositing. All of the ticks of the second lot, except one, deposited eggs, and 75 per cent of the eggs hatched.

The rather low percentage of hatching among the eggs deposited by the undipped ticks was due to the low relative humidity of the air of the room, where the ticks and eggs were kept during the experiments, and it is possible that some of the eggs deposited by the dipped ticks might have hatched had the conditions as to moisture been more favorable.

*Experiment No. 12.*

During the summer and fall for several weeks prior to October 10, 1910, 7 young cattle at the Bureau Experiment Station were artificially infested with ticks by applying larvæ every few days. On the date named 6 of them were sprayed with arsenical solutions by means of a hand spray pump. Three different solutions were used, and 2 cattle were sprayed with each solution. The seventh animal was reserved untreated as a control. All of the cattle were kept after dipping in the pen which they had occupied prior to the treatment, and four days after spraying larval ticks were applied to each animal.

*Lot A.*—The two cattle in this lot were sprayed with the oxidized dip referred to in Experiment No. 11. A sample taken from the vat October 20 showed that oxidation of the arsenic had continued since the taking of the previous sample, September 15, the amount of sodium arsenite present having been reduced to the equivalent of about 0.02 per cent arsenic trioxid,[1] though the total arsenic in solution was the same as before.

[1] Analysis made in Biochemic Division.

At the time of spraying one of the cattle was slightly infested, the other moderately infested with ticks in all stages of development. Three days later the cattle were examined. One of them showed a slight exfoliation of the skin on the dewlap; on the other the skin was unaffected. On one animal a few live nymphs and adults, some of the latter engorged females, were found. On the other there were live ticks in various stages, mostly nymphs, but some engorged females apparently in good condition were noted.

Ten days after the spraying one of the cattle showed exfoliation of the epidermis on the crest of the neck and withers, and on the dewlap, very slight in the latter location. Very slight exfoliation confined almost entirely to the dewlap was noted in the case of the other animal. On one of the cattle a live larva nearly ready to molt was found, also several live males, and females which had evidently molted a few days before the examination. On the other there were 5 apparently healthy engorged females with live males, and a dozen or more newly molted females, all more or less affected by the dip.

October 20, 10 days after the first spraying, the cattle were again sprayed with some of the same dip as before.

Four days later the cattle were examined. Slight exfoliation of the epidermis was found as before. On one a recently molted female and a male were found alive, on the other an engorged female and a recently molted female and 2 males.

Seven days after the second spraying the skin injury was still very slight. A half-grown adult female and a male on one animal and a two-thirds grown adult female on the other animal were the only live ticks found.

Eleven days after the second spraying one of the cattle showed a hard granular exfoliation of the skin on the withers; the other showed no signs of skin injury. No ticks were found on one. On the other there was an engorged female, 2 adult females one-fourth grown, and 3 males.

Fourteen days after the second spraying the exfoliation of the epidermis on the withers was still noticeable in the case of one of the cattle. No ticks were found on this animal. On the other a partially engorged female and a nymph were found to be alive.

Twenty-one days after the second spraying the last examination was made. There were no longer any signs of skin injury. One of the animals was free from ticks; the other had several partially grown adult females on the belly, some of them newly molted.

So far as possible all of the engorged females were collected as they matured on the treated animals, beginning immediately after the first spraying. These were brought to the laboratory and kept under observation in Petri dishes. For comparison engorged and partially engorged ticks were collected from time to time from the untreated

animal which served as a control and these were kept under the same conditions as those from the sprayed cattle.

Immediately after the first spraying 11 engorged ticks were collected from one of the sprayed cattle and 3 from the other. Three of the former died without ovipositing, and 8 deposited eggs, none of which, however, hatched. All 3 of the ticks from the other animal deposited eggs, and 5 per cent hatched.

For comparison it may be noted that all of 29 ticks collected on the same date from the untreated animal deposited eggs, and that 40 per cent of them hatched.

One day after spraying 29 ticks were collected from one of the treated animals, 25 of which deposited eggs. None of the eggs hatched. Forty-five ticks collected the same day from the untreated animal all deposited eggs, 75 per cent of which hatched.

Two days after spraying 8 ticks were collected from one of the treated animals, and 7 of these deposited eggs, but none hatched. All of 14 ticks collected the same day from the untreated animal deposited eggs, of which 4 per cent hatched.

Three days after spraying 8 ticks were collected from one of the treated animals. All deposited eggs, but none of them hatched. All of 8 ticks collected from the unsprayed animal on the same date deposited eggs, but less than 1 per cent hatched.

Four days after spraying 1 tick was collected from one of the sprayed cattle. This tick deposited eggs, but none hatched. On the same date 2 ticks were collected from the untreated animal. Both deposited eggs, but none hatched.

No ticks were collected from the treated cattle for observation later than four days after the first spraying.

*Lot B.*—The two cattle of this lot were sprayed with an arsenical dip freshly made from 91 grams of arsenic trioxid, 84 grams of sodium carbonate (anhydrous), 75 c. c. of pine tar, and 10 gallons of water. Analysis [1] showed an equivalent of 0.234 per cent arsenic trioxid in solution. One of the animals when sprayed was rather heavily infested, the other lightly infested with ticks in all stages of development.

Three days after spraying no injury to the skin was noted. On one of the animals were noted numerous live ticks, nymphs and adults, some of the latter engorged, others partially grown and abnormally swollen from the effects of the dip. On the other there were a few live nymphs and some engorged ticks.

Ten days after spraying one of the cattle showed a very slight exfoliation of the epidermis on the crest and side of neck, and an exfoliation at the base of the tail and thickening of the skin in the anal region. On the other animal there was a slight exfoliation at

[1] Made in Biochemic Division.

the base of the tail and in front of the right shoulder. No live ticks were found on one. On the other several nymphs were noted on the escutcheon as possibly alive, and a cluster of live ticks of various stages from young nymphs to engorged females was found on the inner side of the flank.

Ten days after the first spraying the two cattle in this experiment were sprayed again with an arsenical dip freshly prepared from 7 pounds arsenic trioxid, 6½ pounds sodium carbonate (anhydrous), 0.7 gallon pine tar, and 350 gallons of water, containing an equivalent of 0.22 per cent of arsenic trioxid.[1]

Four days after the second spraying an exfoliation of the epidermis on the brisket, right shoulder, and at the root of the tail was noted on one animal, and an exfoliation at the root of the tail and in the sacral region was observed on the other animal. No ticks were found on one. A live nymph and a recently molted female were found on the other in the right inguinal region.

Seven days after the second spraying the exfoliation of the skin was still slightly noticeable. No ticks were found on one animal. On the other the same 2 ticks noted at the previous examination were found, namely, a nymph and a female.

Eleven days after the second spraying one of the animals showed no signs of epidermal exfoliation. Slight exfoliation was still evident in the case of the other. On the animal which showed tick infestation at the two preceding examinations a young female, a male, and a nymph were found alive in the right inguinal region. A female one-sixth grown and a male were found on the other animal, whose presence was evidently overlooked at the preceding examination.

Fourteen days after the second spraying the evidences of skin injury were still slight. No ticks were found on one of the animals, the female one-sixth grown and the male noted at the preceding examination having disappeared. A partially grown female, a male, and a newly molted female were found in the right inguinal region of the other animal, evidently the same ticks noted at the preceding examination.

Twenty-one days after the second spraying when the final examination was made no ticks were found on either animal. One of the animals still presented a slight epidermal exfoliation at the root of the tail, sides of hocks, and on the escutcheon.

The same procedure with reference to the removal of ticks for further observation was followed as in the case of Lot A.

Thirty-seven ticks were removed from one animal and 2 ticks from the other immediately after the first spraying. Of the former, 6 deposited a very few eggs and none of these hatched, the other 31 dying without depositing eggs. Both of the ticks from the other

[1] Analysis made in Biochemic Division.

animal deposited eggs, none of which hatched. For comparison it may be noted that 29 ticks collected at the same time from the untreated animal (already referred to under Lot A) all deposited eggs, of which 40 per cent hatched.

One day after spraying 31 ticks were collected from the sprayed cattle, 18 of which deposited eggs. None of the eggs hatched. All of the 45 ticks collected on the same day from the untreated animal (as noted under Lot A) deposited eggs, of which 75 per cent hatched.

Two days after spraying 12 ticks were collected from the sprayed cattle, 6 of which oviposited. None of the eggs hatched. The 14 ticks collected from the untreated animal on the same day all deposited eggs, of which 4 per cent hatched.

Three days after spraying 4 ticks were collected from the sprayed cattle. Two of these deposited eggs, but none hatched. All of the ticks, 8 in number, collected from the untreated animal on the same day, deposited eggs. Of these less than 1 per cent hatched, however.

No ticks were collected from the cattle in this lot after the third day subsequent to the first spraying.

The same remarks concerning the effects of the low relative humidity on the eggs of the ticks apply in the case of this lot as in the case of Lot A.

*Lot C.*—The two cattle of this lot were sprayed with a special arsenical dip devised by Mr. Chapin of the Biochemic Division, bearing the laboratory designation of Tick Dip B. It contained potassium arsenite, pine tar, and some soap. The amount of arsenic in solution in a sample of the dip as diluted for use was equivalent to 0.222 per cent arsenic trioxid.[1] Both of the cattle sprayed with this dip were rather heavily infested with ticks in all stages of development.

Three days after spraying a slight epidermal exfoliation on the dewlap and at the root of the tail was noted on one of the animals, and a slight exfoliation on the escutcheon where the ticks had been numerous was noted on the other animal. On one animal numerous live nymphs and adults, some engorged, were observed. Many of the adult ticks were abnormally swollen. On the other animal were observed partially grown adult ticks, alive, but mostly abnormally swollen and dark in color. Some nymphs apparently in good condition were also seen.

Ten days after spraying one of the cattle showed a slight epidermal exfoliation on the crest of the neck, on the shoulders, and on the brisket, and a slight scurf on the side of the neck. The skin of the dewlap was thickened and exfoliating. There was some exfoliation at the base of the tail, on the escutcheon, and inner side of thighs, with thickening of the skin. There was some exfoliation with slight

[1] Analysis made in Biochemic Division.

soreness of the skin on the belly opposite the flank. The other animal showed similar skin conditions, but to a less degree. On the former there was a larva apparently alive located near the root of the tail. No live ticks were found on the other. Dead ticks were numerous on both animals.

Ten days after the first spraying the cattle were sprayed again with Tick Dip B used at the same dilution as before. No analysis was made of the dip used at the second spraying. It is assumed, however, that the percentage of arsenic in the dip was the same as at the first spraying.

Four days after the second spraying the evidences of skin injury were less marked than at the preceding examination. No live ticks were found on either animal.

Seven days after the second spraying exfoliation and thickening of the skin were still noticeable. No live ticks were found on either animal.

Eleven days after the second spraying slight exfoliation of the skin in the anal region and on the escutcheon with considerable thickening in the latter location were noted on one animal. On the other the edge of the dewlap was dry and hard, and there was some exfoliation on the root of the tail. No ticks were found on either animal.

Fourteen days after the second spraying slight evidences of the effects of the dip on the skin were still present. No ticks were found on either animal.

Twenty-one days after the second spraying the evidences of skin injury were still noticeable. No ticks were found on either animal.

The following observations were made on ticks removed from the cattle after spraying and kept in the laboratory:

Immediately after the first spraying 59 ticks were removed from one of the cattle and 18 from the other. All died without depositing eggs. In comparison it may be noted that 29 ticks removed from the unsprayed animal on the same day all deposited eggs, of which 40 per cent hatched.

One day after spraying 15 ticks were collected from the sprayed cattle. Seven of the ticks deposited eggs, of which none hatched. The 45 ticks removed on the same day from the unsprayed animal all deposited eggs, of which 75 per cent hatched.

Two days after spraying 6 ticks were collected from one of the sprayed cattle. Three of these deposited eggs, none of which hatched. Fourteen ticks collected the same day from the unsprayed animal all deposited eggs, of which 4 per cent hatched.

No engorged ticks were collected from the sprayed cattle later than two days after spraying.

*Notes on the untreated animal.*—On the day the cattle in this experiment were sprayed the second time the untreated animal

exhibited a slight epidermal exfoliation on various parts of the body. Ticks in all stages of development were numerous.

Four days after the second spraying of the rest of the cattle the untreated animal showed a slight scurfiness of the skin in various places. Ticks were still numerous, especially on the escutcheon.

Seven days after the second spraying of the rest of the cattle numerous ticks in all stages of development, most abundant on the escutcheon, were noted on the untreated animal.

Eleven days after the second spraying of the rest of the cattle the presence of nymphs and adult ticks, abundant on the escutcheon and lower part of dewlap, was noted on the untreated animal.

Fourteen days after the date of the second spraying a few nymphs and numerous adults were noted on the unsprayed animal.

Twenty-one days after the date of the second spraying numerous adult ticks in various stages of growth were present on the unsprayed animal. One nymph was found at this time.

### ARSENIC, SODA, AND PINE-TAR DIP CONTAINING EMULSIFIED CRUDE PETROLEUM.

*Experiment No. 13.*

Fifty gallons of crude petroleum mixed with 12½ gallons of hot concentrated soap solution were added to the arsenic, soda, and pine-tar dip used in experiment No. 2. A fairly good emulsion was obtained. No analysis of this dip was made, but it may be estimated that it contained about 10 per cent of crude petroleum and an equivalent of somewhat less than 0.172 per cent arsenic trioxid. October 22, 4 cattle were sprayed with this mixture in the same machine as used in experiment No. 2. The machine did not work properly during the spraying of these animals. October 23, 57 cattle were sprayed. The machine worked well and these animals received a thorough spraying. On both dates the cattle were held in the machine at least 10 seconds each. Most of them were grossly infested with ticks in all stages of development.

Many of the cattle were rather severely injured by the treatment, the skin becoming thickened, cracked, chafed, and sore to the touch, with exfoliation, and the animals showed more or less stiffness and lameness as a result of the skin injury. The injurious effects of the treatment were still well marked 8 days after the treatment. The cattle in this experiment were more seriously injured than others of the same herd sprayed with a 25 per cent emulsion of crude petroleum, and were much more seriously injured than those in experiment No. 2 sprayed with the arsenical solution before the addition of the crude petroleum.

Cattle closely examined 7 and 8 days after spraying were free from ticks, and others seen 8 days after spraying during a ride through the herd were apparently free from ticks.

Thirty-eight engorged ticks were removed from some of the cattle 14 hours after spraying. Twenty-nine of these died without depositing eggs. The remaining 9 laid a few eggs, none of which hatched. Thirty-four engorged ticks were removed from the cattle 3 days after spraying. One of these laid a few eggs, none of which hatched; the other 33 died without depositing eggs. Fourteen ticks collected October 22 from untreated cattle and kept under the same conditions as those from the sprayed cattle deposited numerous eggs, most of which hatched. Another lot of 6 engorged ticks taken from untreated cattle on the same date deposited about 1,000 eggs, about 100 of which hatched. None of 10 nymphs collected 14 hours after spraying molted, and 9 nymphs collected 3 days after spraying all failed to molt. All but 4 out of 25 nymphs collected October 22 from untreated cattle and kept under the same conditions as those from the sprayed cattle afterwards molted.

### ARSENIC AND ZINC SULPHATE DIP.

*Experiment No. 14.*

August 7, 1909, a tick-infested calf was dipped at the Bureau Experiment Station in a dip consisting of arsenic trioxid, zinc sulphate, and water, containing 0.476 arsenic trioxid in solution.[1]

In this dip the same ingredients were used and in the same proportion as those used in the so-called "arsenical dip of Trasbot" employed in France for dipping scabby sheep, omitting, however, the aloes which is included in Trasbot's dip, with the further difference also that only about half the arsenic used was brought into solution, although it was submitted to prolonged boiling.

The calf had been artificially infested and at the time of dipping ticks in all stages of development were present. The period of immersion in the bath was two minutes, and after dipping the calf was kept in a noninfested pen. The calf was seriously injured by the dip. The skin in places became much thickened and cracked, with much exfoliation and some loss of hair, and the animal fell off in flesh considerably. Recovery from the effects of the dipping required nearly a month. No ticks matured later than two days after dipping and all that matured after dipping died without depositing eggs. The calf was entirely free from live ticks six days after dipping.

Immediately after dipping, August 7, 49 engorged ticks were removed from the calf. All of these died without depositing eggs.

[1] Analysis made in Biochemic Division.

For comparison it may be noted that 24 out of a lot of 25 small and only partially engorged ticks collected from an undipped animal on the same date and kept under the same conditions deposited eggs which weighed 0.3036 gram, 12 per cent of which afterwards hatched.

August 8, 5 engorged and 7 partially engorged females were collected from the calf, all of which died without depositing eggs. For comparison note that 1 fully engorged and 3 partially engorged females collected from an undipped calf on August 8 and kept under the same conditions as the ticks from the dipped calf all deposited eggs weighing 0.1365 gram, 75 per cent of which hatched.

August 9, after which date no ticks matured on the calf, 6 nearly replete females were collected, all of which died without depositing eggs. For comparison note that 1 female, nearly replete, collected from an undipped calf on the same date and kept under the same conditions as the ticks from the dipped calf deposited eggs weighing 0.0295 gram, 80 per cent of which hatched.

The dip used in this experiment had the effect of destroying not only the younger ticks but also affected the engorged and nearly engorged ticks so seriously that they died without depositing eggs.

Judging from the results of this experiment, the dip used, although it proved very efficacious as a tick killer, has no practical value as a cattle dip on account of its severe effects and the difficulty of dissolving the arsenic in preparing it.

*Experiment No. 15.*

August 8, 1909, 46 fully engorged female ticks were collected from an undipped calf at the Bureau Experiment Station. These were immersed for two minutes in some of the solution used in experiment No. 14, which contained 0.476 per cent arsenic trioxid. After dipping, the ticks were dried on filter paper, placed in a Petri dish, and kept under observation in the laboratory. Forty-four of these ticks died without depositing eggs. The other 2 deposited eggs amounting in aggregate weight to 0.0078 gram, none of which hatched. Out of 46 engorged ticks collected August 8 and kept under the same conditions as the ticks referred to above, except that they were not dipped, 45 deposited eggs whose aggregate weight amounted to 2.5975 grams, and 98 per cent of them hatched. Another lot of 4 females collected August 8 and kept under the same conditions deposited eggs weighing 0.1365 gram 75 per cent of which hatched.

### ARSENIC-ALUM DIP.

*Experiment No. 16.*

August 10, 1909, a calf which had been artificially infested with ticks was dipped at the Bureau Experiment Station in a dip consisting of arsenic trioxid, alum, and water, containing 0.495 per cent arsenic trioxid in solution.[1] This dip is similar to a dip used more or less in Europe for the treatment of sheep scab.

At the time of dipping, ticks in all stages of development were present on the calf. The animal was immersed in the dip for two minutes. After dipping the calf was kept in a noninfested pen.

The skin of the calf was slightly injured by the dipping to the extent that in places some thickening with exfoliation occurred, which was still noticeable August 20, but had disappeared by September 9. The animal was entirely free from ticks within eight days after dipping. No ticks matured on the calf later than three days after dipping. All that matured either died without ovipositing or deposited only a few eggs, none of which hatched.

This dip was very efficacious and produced only slight skin injury. The difficulty of preparing it, however—that is, of dissolving the arsenic trioxid—renders it undesirable for practical use.

August 10, immediately after dipping, 43 engorged and nearly engorged female ticks were collected. All of these died without depositing eggs. Later in the same day 19 engorged females were collected, all but 4 of which died without depositing eggs. These 4 deposited eggs amounting to 0.013 gram in weight, none of which hatched. For comparison with the above it may be noted that 21 out of a lot of 22 females, none fully grown, collected August 10 from an undipped animal and kept under the same conditions as those from the dipped calf deposited eggs aggregating 0.4242 gram in weight, and that 50 per cent of these hatched.

August 11, 18 females (6 engorged and 12 partially engorged) were collected, 3 of which deposited eggs weighing 0.0495 gram, none of which hatched. The other 15 died without depositing eggs. In comparison note that 18 females (4 fully engorged and 14 nearly engorged) collected from undipped cattle August 11 and kept under the same conditions all deposited eggs weighing 0.2441 gram, 40 per cent of which hatched.

August 12, two days after dipping, 14 females (6 fully engorged and 8 nearly engorged) were collected, and 2 of these laid eggs weighing 0.0082 gram. The other 12 ticks died without ovipositing. None of the eggs hatched. In comparison note that 5 females (3 fully engorged and 2 partially engorged) collected from undipped

[1] Analysis made in Biochemic Division.

cattle August 12 and kept under the same conditions all deposited eggs weighing 0.1555 gram, and that 60 per cent of these hatched.

August 13 was the last day on which any ticks matured on the calf in this experiment. On this date 6 females (3 fully engorged and 3 partially engorged) were removed, 1 of which survived to deposit eggs weighing 0.0293 gram. None of these hatched. In comparison note that 17 engorged females collected from an undipped calf August 13 and kept under the same conditions as those from the dipped calf all deposited eggs weighing 0.8953 gram, and that 97 per cent of these hatched. It may also be noted that 1 engorged female removed from an undipped calf August 13, and kept under the same conditions as the ticks from the dipped calf, deposited eggs weighing 0.0426 gram, and that 40 per cent of these hatched.

*Experiment No. 17.*

Fifty-nine engorged female ticks, collected August 10, 1909, from cattle at the Bureau Experiment Station, were immersed two minutes on August 11 in some of the dip used in Experiment No. 16, which contained 0.495 per cent arsenic trioxid. After dipping, the ticks were dried on filter paper, placed in a Petri dish, and kept under observation in the laboratory. Fifty-seven of these ticks died without depositing eggs. The other two deposited eggs whose aggregate weight amounted to 0.0123 gram. None of these eggs hatched.

Fifty-eight in a lot of 59 undipped ticks, collected at the same time as those just referred to, deposited eggs whose aggregate weight equaled 2.773 grams, and 97 per cent of which hatched, having been kept under the same conditions as those from the dipped ticks.

## SODIUM ARSENATE DIP.

*Experiment No. 18.*

November 10, 1910, 60 engorged ticks collected from an infested bull at the Bureau Experiment Station were divided into 3 lots of 20 each and kept in the laboratory in Petri dishes, all under similar conditions. Sufficient moisture to insure the hatching of normal eggs was provided by the presence of sand in the dishes, which was kept moist.

Lot No. 1 was dipped two minutes on November 10 in a neutral solution of sodium arsenate containing an equivalent of 0.22 per cent arsenic trioxid.[1]

Lot No. 2 was dipped two minutes on the same date in a slightly alkaline solution of sodium arsenate containing an equivalent of 0.22 per cent arsenic trioxid.[1]

[1] Solution prepared in Biochemic Division.

Lot No. 3 was not dipped.

All but one of the first lot of ticks deposited eggs, of which 1 per cent hatched. All of the second lot deposited eggs, of which 2 per cent hatched. The third lot of ticks, which were not dipped, all deposited eggs, of which 99 per cent hatched.

### SODIUM SULPHARSENITE DIP.

*Experiment No. 19.*

Twenty-two engorged ticks, collected October 19 and 20, 1910, from an infested bull at the Bureau Experiment Station, were dipped two minutes, October 21, in a slightly alkaline solution of sodium sulpharsenite containing an equivalent of 0.22 per cent arsenic trioxid.[1] After dipping, these ticks were placed in a Petri dish and kept under observation in the laboratory.

On the same date 22 engorged ticks collected at the same time and from the same animal as the preceding lot were dipped two minutes in an arsenic, soda, and pine-tar dip, made October 20, which contained an equivalent of 0.22 per cent arsenic trioxid.

A third lot of 22 engorged ticks also collected at the same time and from the same animal as the other two lots was kept under observation undipped. Except as to dipping, all three lots were handled in the same manner and kept under the same conditions.

Of the lot dipped in sodium sulpharsenite all but three deposited eggs. November 11 about half the eggs were normal, but none hatched. All of the ticks dipped in the arsenic, soda, and pine-tar dip died without ovipositing. All of the undipped ticks deposited eggs, practically all of which were normal on November 11. Less than 1 per cent of the eggs hatched.

The low relative humidity of the air of the laboratory was unfavorable to the hatching of the eggs in this experiment.

### POTASSIUM ARSENITE DIP CONTAINING SOAP.

*Experiment No. 20.*

Twenty cattle heavily infested with ticks—some very heavily—were selected from a herd on the Rincon ranch, near Gregory, Tex., and these animals were dipped June 25, 1910. The dip used was a proprietary arsenical mixture. When diluted the dip contained an equivalent of 0.202 per cent arsenic trioxid [2] in the form of potassium arsenite. It also contained some soap in addition to other ingredients of minor importance. The vat used was about 93 feet in length at the surface of the dip. Each animal was in the bath from 30 to 60 seconds. After dipping, some of the cattle were kept in disin-

[1] Solution prepared in Biochemic Division. [2] Analysis made in Biochemic Division.

fected pens and some on infested pasture. Five to nine days after dipping an exfoliation of the epidermis appeared, rather marked in the case of 2 bulls, but generally slight in the case of the remaining animals, only 2 of which exhibited evidences of more than very mild skin injury. One of these showed a rather severe exfoliation on the escutcheon, thighs, dewlap, and other parts of the body, and the other showed a rather severe exfoliation of the skin on the dewlap, the exfoliation on the posterior parts of the body being slight. The exfoliation in the case of the 2 bulls which were dipped but once was described as rather severe, causing a loss of hair on the inner side of the thighs. In no instance, however, was the exfoliation preceded by noticeable inflammation.

July 5, 10 days after the first dipping, all but 3 of the cattle were dipped a second time in the same vat and in the same dip, to which more water had been added. At the second dipping the dip contained an equivalent of 0.197 per cent arsenic trioxid.[1] Following the second dipping the cattle which had been on infested pasture between dippings were returned to the infested pasture, except 2 which were placed in a disinfected pen. Those which had been in disinfected pens between dippings were returned to the same pens.

The cattle were examined individually on June 25, before dipping, and every few days thereafter, the final examination being made on July 18, two weeks after the second dipping.

Eight to 13 days after the second dipping a fresh exfoliation of the epidermis became evident on some of the animals, but it was, as a rule, much less marked than the exfoliation following the first dipping.

Within four days after the first dipping most of the ticks were dead. All but 7 of the cattle, so far as could be determined from careful examination, were free from live ticks 9 days after the first dipping. At that time the ticks found alive were 2 recently molted females, 8 males (6 of them newly molted), and 6 nymphs. The following day an additional male was found, making 17 the total recorded number of live ticks present on the cattle just prior to the second dipping.

None of the 3 cattle which were dipped but once and subsequently kept in a disinfected pen showed any infestation after July 2, 7 days after dipping. A very plump female one-fourth of an inch long was found on one of the twice-dipped cattle 2 days after the second dipping. This tick was found dead 2 days later. Four days after the second dipping a very plump female one-third of an inch long was found on another animal. This tick was removed and placed in a pill box. It died without depositing eggs. At the final examination a female tick which had molted several days before was found. Except for larvæ which were found at the final examination on the cattle which occupied infested pasture, these 3 ticks were all that

[1] Analysis made in Biochemic Division.

were found upon the cattle subsequent to the second dipping. Most of the larvæ found at the final examination were not more than 1 to 2 days old (reckoning from date of attachment). Only one was found which was older. This one had possibly been attached for as long as 4 days.

From time to time after the first dipping ticks were removed from the dipped cattle and placed in boxes for further observation, and at the same time ticks were removed from undipped cattle and kept under the same conditions for comparison with those from the dipped cattle.

All of the engorged females (10) removed from the cattle immediately after dipping died without depositing eggs. Four out of 20 partly engorged females deposited eggs, none of which hatched. Eleven engorged and 25 partly engorged females removed from undipped cattle on the same date deposited eggs, about 50 per cent of which hatched.

Two days after dipping, 48 engorged and 26 partially engorged females were removed from the dipped cattle. About 20 of the former and 5 of the latter deposited eggs. None of the eggs laid by the latter hatched and about 1 per cent of those laid by the former hatched. On the same date 14 female ticks not more than half grown were removed from undipped cattle. About 3 per cent of the eggs deposited by these ticks hatched.

Three days after dipping, 22 fully engorged and 18 partially engorged ticks were removed from the dipped cattle. About 10 of the former oviposited. Some of the latter also deposited eggs, none of which hatched. Less than 1 per cent of the eggs deposited by the engorged females hatched. On the same date 1 engorged and 13 partially engorged females were removed from undipped cattle. Most of these deposited eggs, and about 10 per cent of the eggs hatched.

Four days after dipping, 3 partially engorged females were removed from the dipped cattle. All of these died without depositing eggs. On the same date 3 females one-fourth to one-half grown were removed from undipped cattle. These deposited eggs, 60 per cent of which hatched.

Five days after dipping, 1 engorged female was removed from one of the dipped cattle. This tick died without ovipositing. On the same date 1 engorged and 2 two-thirds grown females were removed from an undipped bull. All of these deposited eggs, 95 per cent of which hatched.

Six days after dipping, a female tick not more than one-half grown was removed from one of the dipped cattle. This tick died without depositing eggs.

Fourteen days after the first dipping and 4 days after the second dipping, a very plump female one-third of an inch long was

removed from one of the dipped cattle. This tick died without depositing eggs.

Immediately after dipping, 12 nymphs were removed from the dipped cattle. None of these molted. At the same time 20 nymphs were removed from undipped cattle. All but one of these molted.

Two days after dipping, 17 nymphs were removed from the dipped cattle. None of these molted. On the same date 2 nymphs were removed from undipped cattle, and both molted.

Three days after dipping, 41 nymphs were removed from the dipped cattle. None of these molted.

Four days after dipping, 54 nymphs were removed from the dipped cattle. None of these molted. On the same date 42 nymphs were removed from undipped cattle, 27 of which molted.

Five days after dipping, 46 nymphs were removed from the dipped cattle. None of these molted. On the same date 12 nymphs were removed from an undipped bull, and 10 of them molted.

Six days after dipping, 1 nymph was removed from one of the dipped cattle. This nymph failed to molt.

*Experiment No. 21.*

This experiment was conducted under the supervision of Dr. Dick E. Warner, veterinary inspector, assisted by Mr. Charles H. Gibson, agent in tick eradication, both of the Bureau of Animal Industry. The following account is summarized from Dr. Warner's report:

October 26, 1910, 20 head of tick-infested cattle were dipped on the Woodley ranch near Tulsa, Okla. These cattle were all grossly infested with ticks in all stages of development, including some larvæ. The infestation was most pronounced along the inside of the thighs, on the escutcheon, neck, dewlap, and along the anterior border of the scapula. The animals were infested to a less degree on all other parts of the body. In several instances the infestation reached the degree known as "shingled," and in some instances ticks were noted within the ears. All the cattle carried a heavy winter coat of hair. All were in good health at the time of dipping with the exception of 2, which presented the appearance of having recently suffered from an attack of fever. During the experiment these 2 animals constantly improved in condition.

The dip used was a proprietary arsenical dip of the same brand as that used in experiment No. 20. When diluted for use it contained an equivalent of 0.224 per cent arsenic trioxid.[1]

The vat in which the cattle were dipped was 31 feet in length at the surface of the dip. Each animal was held in the bath from 13 to 15 seconds. After dipping, 4 of the cattle were placed in a tick-free pen, and the remaining 16 in a small infested pasture. In view of the cool

[1] Analysis made in Biochemic Division.

weather prevailing, it is probable that the latter were exposed to but slight chances of reinfestation. A heavy frost occurred every night but one during the experiment, and at times ice formed during the night to a thickness of one-third of an inch. There was no rain during the experiment.

After dipping, the cattle were examined at intervals of a few days. A slight exfoliation of the epidermis was noted, beginning 4 days after dipping. At no time did this exfoliation become extensive, nor was it accompanied by inflammation. No injury to the skin or hair was noted.

Most of the ticks had disappeared by the fourth day after dipping. No live larval ticks were found subsequent to dipping. Eight days after dipping 2 live males were found on 1 animal. On 8 cattle 14 nymphs apparently alive were found 8 days after dipping. On 18 of the cattle 99 live females, from newly molted to one-half grown, were found 8 days after dipping. Thirty-one female ticks over half grown were found on 6 of the cattle 8 days after dipping. Thirteen of these were stated to be mature. Two cattle were free from ticks 8 days after dipping. One of these had been kept in the disinfected pen, the other in the infested pasture.

November 4, 18 of the cattle were dipped again. The other 2 were not dipped a second time, but were kept under observation for 23 days after dipping and were still infested with ticks at the end of this time. Both of these animals occupied the infested pasture after dipping. No live nymphs were noted on one of these cattle subsequent to October 30. One nymph apparently alive was noted on the other 8 days after dipping, but none was found subsequently. Twenty-three days after dipping the only ticks found on the cattle which were dipped but once were 3 females on one and 1 female on the other.

At the second dipping the dip which was left in the vat since the first dipping was used. A sample taken at the time of the second dipping showed the presence of an equivalent of 0.233 per cent arsenic trioxid.[1] Each animal dipped was held in the bath 13 to 15 seconds, except one, which was held but 9 seconds. Following the second dipping 12 of the cattle dipped were placed in the infested pasture and 6 in the disinfected pen. Four of these 6 had occupied the pen between the 2 dippings; the other 2 had been in the infested pasture.

The effects of the second dipping on the skin were described as extremely mild, consisting of slight exfoliation, noted in the case of only 2 animals. Twelve days after the second dipping the exfoliation due to the first dipping continued in a mild form, unaccompa-

[1] Analysis made in Biochemic Division.

nied by inflammation, and without noticeable injury to the hair or skin.

A nymph apparently alive was found on each of 2 cattle out of a total of 7 examined two days after the second dipping. No live nymphs were afterwards found on any of the twice-dipped cattle. No live males were found subsequent to the second dipping. On 5 of the 7 cattle examined, 14 female ticks were found, ranging in development from newly molted to two-thirds grown. The other 2 cattle were free from ticks and none was afterwards found on them. Four days after the second dipping 11 cattle were examined and 2 found to be infested. Two female ticks one-sixth grown and 1 female tick two-thirds grown were found on 1 of the 2 infested cattle, and 1 female tick about one-half grown on the other, a total of 4 ticks. The other 9 cattle were free from ticks and none was found on them subsequently. Six days after the second dipping 8 cattle were examined and 1 of them was found to be infested with a female tick one-half grown. This animal was 1 of the 2 found infested 4 days after the second dipping. Eight days after the second dipping 10 cattle were examined, including the 1 found infested 6 days after dipping. No live ticks were found. Ten days after the second dipping 8 cattle were examined and on 1 of them was found a female tick over one-half grown. This was the last tick found subsequent to the second dipping. The animal on which it was found was 1 of those examined 6 days after dipping and at that time was apparently free from ticks. The tick showed evidences of the injurious effects of the dip. Two days later or 12 days after the second dipping this tick had disappeared. Fourteen days after the second dipping all of the twice-dipped cattle were free from ticks.

From time to time after the first dipping ticks were removed from the dipped cattle and placed in boxes for further observation. Ticks were also removed from undipped cattle and kept under similar conditions for comparison with those from the dipped cattle.

*Engorged and partially engorged females.*—One hour after the first dipping 100 engorged females were removed from the dipped cattle. All of these died without depositing eggs. Another lot of 100 engorged females removed at the same time from undipped cattle all deposited eggs.

Two days after dipping 60 engorged or nearly engorged female ticks and 10 half-grown females were removed. The latter died without ovipositing. Of the former, 48 deposited eggs in number less than normal. At the same time 40 engorged or nearly engorged females and 30 half-grown females were removed from undipped cattle. All of the former and 3 of the latter deposited eggs.

Four days after dipping 15 engorged females and 12 one-third to one-half grown females were removed from the dipped cattle. None

of the latter deposited eggs. Six of the former deposited eggs in number less than normal. On the same date 15 engorged females and 12 one-third to one-half grown females were removed from undipped cattle. All of the former and none of the latter deposited eggs.

Six days after dipping 12 engorged females and 7 one-third to one-half grown females were removed from the dipped cattle. Three of the former deposited eggs in number less than normal and none of the latter deposited eggs. On the same date 12 engorged or nearly engorged females and 7 one-third to one-half grown females were removed from undipped cattle. All of the former and none of the latter deposited eggs.

The ticks which had been removed from the cattle and eggs which they had deposited were sent to the laboratory of the Zoological Division at Washington in the early part of December. They were in such poor condition when received that it was considered useless to make any further observations upon them.

*Nymphs.*—Two days after dipping 15 nymphs were removed from the dipped cattle. All of these died without molting. On the same date 20 nymphs were removed from undipped cattle. Two of these molted, the others died without molting.

Four days after dipping 15 nymphs were removed from the dipped cattle. Two of these molted, the others died without molting. On the same date 15 nymphs were removed from undipped cattle. Three of these molted, the others died without molting.

Six days after dipping 4 nymphs were removed from the dipped cattle. All died without molting. On the same date 4 nymphs were removed from undipped cattle. All died without molting.

### EFFECT OF REPEATED APPLICATIONS OF THE ARSENIC, SODA, AND PINE-TAR DIP.

*Experiment No. 22.*

This experiment, though not concerned with the efficacy of arsenical dips, may be recorded here inasmuch as it has a bearing upon the question of the injurious effects of these dips upon cattle.

Beginning June 23, 1910, 2 lots of calves of 3 head each were dipped repeatedly at intervals until near the end of October. A third lot of 3 was kept under observation undipped. All 3 lots were kept together in the same yard and stable at the Bureau Experiment Station under the same conditions except as to dipping.

Lots A and B were dipped June 23 in a dip made from 7 pounds of arsenic trioxid, 6½ pounds of sodium carbonate (anhydrous), 0.7 gallon of pine tar, and sufficient water to make a total of 350 gallons.

This dip contained sodium arsenite equivalent in amount to 0.217 per cent arsenic trioxid.[1]

One week later lot A was dipped again in the same dip and thereafter was dipped every two weeks until October 20, when the last dipping was made. At the last dipping a freshly prepared dip was used, which was mixed in the same proportions as the dip made in June, and contained sodium arsenite in solution equivalent to 0.22 per cent arsenic trioxid.[2]

Lot B was dipped every three weeks after the first dipping, using the dip made June 23. The last dipping was made on October 27. At this dipping the freshly prepared dip made October 20 was used.

The cattle of lot A were accordingly dipped 10 times and those of lot B 7 times. Each animal when dipped was kept in the bath 2 minutes. Once a week the cattle were weighed and examined.

One week after the first dipping 5 of the 6 animals dipped showed a slight scurfy condition of the skin on different parts of the body, but no irritation. The hair was rather dry and rough.

Two weeks after the first dipping and one week after the second dipping, one of the cattle in lot A showed a moderate dandruff-like exfoliation on the neck, inner side of thighs, and the flank. Another showed some roughness of the skin on the inner side of the thighs and the third showed a very slight roughness of the skin in the same location. One of the cattle in lot B, two weeks after dipping, showed considerable epidermal exfoliation of a dandruff-like character on the brisket and inner side of thighs. Another showed a very slight roughness on the inner side of one thigh, and the third a rough exfoliation on the inner side of both thighs.

Three weeks after the first dipping and two weeks after the second dipping, one of the cattle in lot A had a slight scurf in the hair on the brisket and on the elbows. Another showed a slight roughness of the skin on the inner side of the thighs. The skin of the third calf was normal. On the same day one of the animals of the other lot which had been dipped 3 weeks before was scurfy on the brisket, and the skin on the inner side of the thighs was slightly rough. Another had a slight loose scurf on the inner side of the thighs, and the third showed some scurf and scale on the inner side of thighs, peeling off with slight loss of hair.

By August 4 all evidences of any injurious action of the dip on the skin of the dipped animals had disappeared, and no signs of any action of the dip on the skin were thereafter observed except that at times the hair of the dipped animals appeared to be somewhat dryer than that of the undipped animals. The freshly prepared dip used

[1] Analysis made in Biochemic Division of a sample taken June 23.
[2] Analysis made in Biochemic Division.

at the final dipping had no noticeable effect upon the skin. During the progress of the experiment the cattle of all three lots became more or less affected with ringworm, upon which the dip had no apparent effect.

July 29, one of the cattle in lot C, the undipped lot, died. The lungs were pneumonic with many lung worms present.

August 13, one of the animals in lot B died after symptoms of pneumonia. On post-mortem the lungs were found to be in a pneumonic condition, and the trachea was occluded with a mass of lung worms.

Other calves in the three lots of cattle presented symptoms from time to time suggesting the presence of lung worms, but the two just referred to were the only ones which died. Another calf was added to lot C to take the place of the one which died, but lot B was continued after August 13 with only two calves.

The three calves in lot A on June 23 weighed 172.5 pounds, 210 pounds, and 235 pounds, respectively, and on November 3, at the close of the experiment, 240, 260, and 315 pounds, respectively. The two calves in lot B which survived weighed, respectively, 215 and 242.5 pounds at the beginning of the experiment and 285 and 365 pounds at the end of the experiment.

The two surviving calves of the three original animals in lot C, the undipped lot, weighed, respectively, 232.5 and 342.5 pounds at the beginning of the experiment and 415 and 570 pounds at the end of the experiment. The calf substituted for the one that died weighed 180 pounds August 4 and 240 pounds at the close of the experiment. At times the animals in all three lots fell back in weight, but on the whole they showed a gradual increase from first to last.

From the foregoing figures it is seen that the average gain in weight of the cattle in lot A was 32 per cent, in lot B 42 per cent, and in the undipped lot C, assuming that the substitute calf gained 30 pounds from June 23 till August 4, when it entered the experiment, 68 per cent. Apparently the gain in weight was diminished as a result of dipping, but the number of cattle in the experiment was too small for any definite conclusion to be drawn in regard to this point. The fact also that some of the cattle were suffering more or less from lungworm infection is a factor which would affect the validity of any general conclusion that might be drawn from this experiment as to the relative gain in weight shown by cattle repeatedly dipped in arsenical dip, as compared with undipped cattle.

In view of the oxidation of the dip used in the present experiment which began to occur at some time subsequent to the third dipping of lot A and the second dipping of lot B, the value of the experiment is less than it would have been had freshly made dips been prepared from time to time. The effects of repeated applications of freshly

made dips might, of course, have proved more serious than those which occurred as a result of the repeated use of the oxidized dip. The experiment was therefore unsatisfactory so far as concerns the question as to the amount of injury to cattle which may be expected when they are dipped repeatedly at intervals of two to three weeks during a period of several months in an arsenic, soda, and pine-tar dip containing sodium arsenite equivalent to 0.22 per cent arsenic trioxid.

## DISCUSSION OF RESULTS.

### EFFECTS OF ARSENICAL DIPS ON CATTLE.

The effects of the dips upon the cattle in the various experiments were almost invariably slight.

No constitutional symptoms were observed except in one experiment (No. 14), in which a dip containing 0.476 per cent of arsenic trioxid was used, and these may have been secondary to severe skin lesions. The calf dipped in this strong solution lost considerably in weight and did not begin to recover from the effects of the dip until about a month after dipping. In another experiment (No. 16) a calf dipped in a still stronger solution (0.495 per cent) of arsenic trioxid showed no signs of injury other than slight skin injury. Cattle not infested with ticks, dipped repeatedly in a dip containing an equivalent of about 0.22 per cent arsenic trioxid at intervals of two and three weeks gained less in weight than other uninfested cattle kept under the same conditions undipped, but it is uncertain whether this difference was due to the dipping. (See experiment No. 22.)

In all cases in which cattle were dipped or sprayed once or twice in arsenical dips containing an equivalent of from 0.16 to 0.24 per cent arsenic trioxid the injurious effects observed were confined to the action of the dips upon the skin, and scarcely ever was this action more than very mild, though in some cases the animals were treated in hot weather when the injurious effects from dipping are especially likely to appear. The signs of the effects of dipping on the skin in various instances became evident in from 3 to 9 days after the treatment, at which time a more or less well-marked epidermal exfoliation or dandruff-like peeling of the superficial layers of the skin appeared, confined as a rule to the dewlap, neck, escutcheon, inner side of thighs, and scrotum. No marked inflammation preceded the exfoliation, though occasionally a slight irritation of the skin in places was observed.

In a number of cases the skin became somewhat thickened on certain parts of the body, namely on the escutcheon, inner side of the thighs, dewlap, and neck. Rarely was cracking of the thickened skin observed. In one experiment (No. 13) in which cattle were sprayed once with an arsenical solution containing an equivalent of about 0.17

per cent arsenic trioxid to which had been added 10 per cent crude petroleum emulsified with soap, rather severe skin injury was observed in the case of some of the animals, consisting in exfoliation, thickening, and cracking of the skin, with evident soreness, which caused the animals to become stiff and lame. These effects were apparently largely due to the oil, as the skin of cattle sprayed in the same dip before the addition of the crude petroleum showed scarcely any signs of injury (experiment No. 2). In the case of a few animals in some of the experiments a slight loss of hair accompanied the exfoliation. Bulls seemed to be more liable to skin injury than cows and steers. The effects of a second dipping so far as observed were always less than those of the first. When fresh exfoliation occurred as a result of a second dipping given within two weeks after the first, it first became noticeable in from 8 to 13 days after the second dipping.

In this connection it should be noted that it is a matter of common observation and shown very clearly in many of the experiments detailed in this paper, that there is a great difference in the susceptibility of individual animals to the effects of dips applied in the same way and under similar conditions. The skin affections produced by a dip appear also to depend on the method employed in applying it. Watkins-Pitchford [1] has found that an arsenical dip which is satisfactory from the standpoint of its effects on the skin when used as a spray, is entirely too strong when used as a dip.

In our experiments, cattle dipped ten times with an interval of one week between the first two dippings and with an interval of two weeks between the second and third and succeeding dippings and cattle dipped seven times at intervals of three weeks showed scarcely any evidences of the effects of the dip upon the skin (experiment No. 22). The dip used in this experiment originally contained sodium arsenite equivalent to 0.217 per cent arsenic trioxid, but at some time between three weeks and three months after the first dipping the sodium arsenite had become largely oxidized to sodium arsenate. It is probable that sodium arsenate is less active on the skin than sodium arsenite, hence it is possible that if a freshly made arsenical dip had been used at each dipping, the repeated applications might have had more effect upon the cattle, though it should be noted that at the tenth dipping of one lot of cattle, and the seventh dipping of the other lot, a freshly prepared dip containing an equivalent of 0.22 per cent arsenic trioxid was used without producing any noticeable skin injury.

In one experiment (No. 12, lot C) in which a dip, containing an equivalent of 0.222 per cent arsenic trioxid with some soap, was used, the effects on the skin, though not serious, were somewhat more marked

[1] Natal Agricultural Journal, Pietermaritzburg, vol. 12 (4), 1909, pp. 436–459; vol. 15 (5), 1910, pp. 577–602.

than those usually observed following the use of a simple arsenic, soda, and pine-tar dip, containing the same percentage of arsenic. The effects of a proprietary dip, which contained soap and other ingredients of minor importance in addition to arsenic, as observed in two experiments (Nos. 20 and 21), were apparently somewhat greater than those resulting from the above-mentioned dip containing soap or the ordinary arsenic, soda, and pine-tar dip.

The following conclusions may be drawn from the various experiments as to the effects of arsenical dips upon cattle:

Cattle may be safely dipped or sprayed with an arsenical dip containing an equivalent of 0.24 per cent arsenic trioxid or less, and the treatment once repeated seven or more days later,[1] the only injury to be expected as a rule being more or less epidermal exfoliation, and sometimes slight soreness or tenderness of the skin, local in character.

It is understood in stating the foregoing conclusions that accidents resulting from a lack of proper precautions to avoid the drinking of the dip by cattle are excluded from consideration, and it should also be noted that cattle are liable to suffer severely after dipping, especially in hot weather, if driven long distances, or even if allowed to run short distances so that they become overheated. This latter fact is stated on the basis of observations made by various persons who have had considerable practical experience in the use of arsenical dips. On the whole, however, in view of the hundreds of thousands of cattle on farms and ranches which have been treated with arsenical dips under all sorts of conditions, the number of cases of injury reported has been remarkably small.

In this connection it is of interest to note that Watkins-Pitchford [2] in observations made in South Africa, finds that dipping work oxen every fifth day in an arsenical dip called the "Laboratory Dip" (containing as its essential ingredients 8½ pounds of arsenite of soda, 80 per cent arsenic, to 400 gallons (imperial)[3] of water) does not interfere in any way with cattle being worked regularly.

## EFFECTS OF ARSENICAL DIPS ON TICKS.

The experiments discussed in the present paper have fully confirmed the observations of various investigators and practical users of arsenical dips who have found that ticks are very sensitive to arsenic. Little is known, however, as to the avenue by which arsenic enters the body of ticks when arsenical dips are used.

[1] If many treatments are given the intervals between treatments should not be less than two weeks.
[2] Loc. cit.
[3] One imperial gallon equals approximately 1.2 U. S. gallons.

W. F. Cooper[1] states that he has proved "that on the application of an arsenical solution to the skin of a beast, the arsenic penetrated the skin and was to be found in all the tissues of the beast, and further, that this took place very rapidly." In his experiments a considerable amount of arsenic was found in blood taken from the heart as early as eighteen hours after dipping. Contrary to the results obtained by Mr. Cooper, a committee appointed by the board of health, Natal, South Africa (Agricultural Journal of the Cape of Good Hope, vol. 37, No. 6, December, 1910, p. 699), has found that no trace of arsenic was present in the muscles, liver, kidneys, or stomach of cattle dipped repeatedly at short intervals in arsenical solutions. With regard to the presence of arsenic on the coat and in the skin of animals treated regularly with an arsenical dip, Watkins-Pitchford[2] has furnished some interesting observations. He appears to have shown by analysis of samples of skin a foot square from animals that have been dipped or sprayed regularly, that there is an accumulation of arsenic in the skin up to a certain maximum amount which is rather constant and can not be materially raised by shortening the interval between treatments. He believes that there is not merely a mechanical deposition of arsenic in the skin, but that the amount is controlled by vital processes, any excess of arsenic beyond a certain amount being rapidly taken up by the blood and eliminated in the urine. The amount of arsenic in the hair and scurf is raised by spraying the skin immediately after death, while that in the skin, according to the statement of the author, is not, but the evidence presented on this last point is not complete. It was also found that the amount of arsenic in the hair and scurf of a square foot of skin was always greater than that in the skin itself.

The same author has shown by experiments, which, however, are rather limited, that animals that have been treated with an arsenical dip are poisonous to ticks; that this toxicity increases with the number of treatments, and that in regularly treated animals, it is less, in accordance with the length of the period elapsing after the last treatment. It was also found that when infested animals regularly treated and others not thus treated were dipped, the ticks on the former perished much more quickly than on the latter.

That ticks are not killed by arsenic present in the blood, the author claims to have shown by spraying an animal all over, except on a certain area where ticks had been placed, when the ticks remained unaffected. On the other hand, the poisonous effects do not appear to be due to a simple deposition of arsenic on the skin, because when ticks are permitted to attach to an area of skin, in a regularly treated animal, which has been previously shaved and washed to remove any

[1] Journal of Agricultural Science, vol. 3, part 3, p. 288, Cambridge, 1910.
[2] Natal Agricultural Journal, vol. 15 (3), pp. 312-329, Pietermaritzburg, 1910.

arsenic on the surface, they nevertheless succumb. Some interesting observations were also made with regard to the persistence of arsenic in the hair. In one instance arsenic was found in the hair 6 months and in another 7 months after treatment. A case is referred to in which 3 inches of rainfall did not lower appreciably the amount of arsenic in the coat.

Although Watkins-Pitchford's observations indicate that arsenic accumulates in the skin of cattle when they are dipped repeatedly, it is certain that the action of arsenical dips is not entirely dependent upon the arsenic which ticks may obtain from the skin for the reason that ticks removed from cattle immediately after dipping may afterwards exhibit evidences of having been acted upon by the dip. Our slight knowledge of the mechanism of the action of arsenic upon ticks, therefore, allows only the general statement that when arsenical dips are used the poison enters the bodies of the ticks in one or more of the following four ways, namely, (1) through the mouth; (2) through the breathing pores; (3) through other openings of the body; or (4) by absorption through the cuticle. As a corollary to this statement it may be added that the poisonous action of these dips upon ticks is certainly not entirely dependent upon the arsenic which may be ingested indirectly from the skin of cattle after treatment, but is largely, if not chiefly, dependent upon that absorbed or ingested directly as a result of immersion in the dipping fluid.

### FEMALE TICKS.

It was noted in the various experiments that, as a rule, after cattle had been treated with arsenical dips the number of female ticks maturing became rapidly less day by day, and that it was exceptional to find any engorged ticks present a few days after the treatment. It is therefore evident that after treatment with an arsenical dip the vast majority of the young adult females die before they reach the engorged stage, and that the younger they are the less likely are they to survive and become engorged.

In six experiments the cattle were found to be free from engorged ticks three to five days after the first treatment, in four other experiments they were free seven to nine days after treatment, in another they were nearly free five days after treatment, in another experiment all that were examined were free from engorged ticks eight days after treatment, and in two other experiments the cattle were nearly free from engorged ticks eight days after treatment. An idea of the marked effect of treatment upon female ticks may be obtained from the observations made in one experiment (No. 5) in which a record was kept of the number of ticks which reached the engorged stage on 2 calves after dipping in an arsenical dip containing an equivalent of 0.16 per cent arsenic trioxid. This dip contained considerably less arsenic than the dips usually employed. A third calf was kept under observation undipped, and the number of ticks maturing

on this animal from day to day was recorded, as in the case of the 2 dipped calves. On one of the dipped calves 1,340 ticks and on the other 1,907 ticks reached engorgement during the first week after dipping. From the undipped calf 968 engorged ticks of which a record was kept were collected during the same period. Subsequent to the first seven days after dipping only 67 and 37 ticks, respectively, reached engorgement on the dipped animals, whereas more than a thousand reached full maturity on the untreated calf.

A question of great importance is that of the fate of the ticks which reach engorgement and fall from cattle subsequent to treatment with arsenical dips. In order to obtain data bearing upon this question engorged ticks were collected from the cattle in the various experiments immediately after treatment and on successive days thereafter, and kept under observation. Observations were likewise made upon ticks removed on corresponding dates from untreated cattle. These ticks were kept under the same conditions as those from the treated cattle, and thus served as "controls" or "checks" upon the latter. Excluding from consideration one experiment (No. 5 referred to in the preceding paragraph) in which an unusually weak arsenical dip was used, about 70 lots of ticks varying in number from 1 to 100 each were removed from treated cattle in the various experiments. A somewhat smaller number of lots of ticks from untreated cattle were kept under observation as controls, as in several cases the same lot of ticks from untreated cattle was utilized as a control for several lots from treated cattle. Reviewing the observations recorded relative to the ticks removed from cattle, it may be noted that whereas in many of the lots from treated cattle all of the ticks died without ovipositing, in most cases some of the ticks deposited eggs, the percentage of ticks ovipositing usually being low although in rare instances as high as 100 per cent (Tables 1 to 7, column 4). In the control lots the number of ticks ovipositing was almost always 100 per cent (Tables 1 to 7, column 8).

A marked difference is also apparent with reference to the number of eggs deposited by ticks from treated and from untreated cattle. Ticks from treated cattle which survived to deposit eggs nearly always deposited a much smaller number than ticks from untreated cattle (Tables 1 to 7, columns 5 and 9).

Moreover, not only were the eggs deposited by ticks from treated cattle less numerous but they rarely hatched. On the other hand in only one instance among the control lots did all the eggs fail to hatch (Tables 1 to 7, columns 6 and 10). This was due to the lack of proper moisture, and the same circumstance explains the rather low percentage of eggs which hatched in several other control lots. In great contrast to the high percentage of eggs hatching among those deposited by ticks from untreated cattle, is the fact that out of approxi-

mately 70 lots of ticks [1] from treated cattle only 4 lots deposited eggs which hatched. The data concerning these 4 lots of ticks are as follows: Three ticks, removed from cattle immediately after spraying with a dip containing an equivalent of 0.217 per cent arsenic trioxid but in which the sodium arsenite had become largely oxidized to sodium arsenate, deposited eggs of which 5 per cent hatched (experiment No. 12). Twenty out of 48 ticks removed from cattle two days after dipping in a dip containing an equivalent of 0.202 per cent arsenic trioxid deposited eggs of which 1 per cent hatched (experiment No. 20), and in the same experiment 10 out of 22 ticks removed three days after dipping deposited eggs of which less than 1 per cent hatched. The fourth case was that of a tick removed from a calf four days after dipping in a dip containing an equivalent of 0.215 per cent arsenic trioxid. This tick deposited numerous eggs about half of which hatched (experiment No. 6). Judging from these results it would appear that the hatching of eggs deposited by ticks which survived treatment with arsenical dips is a rather rare occurrence. Furthermore, it has been noted that the larvæ from eggs deposited by females which have been subjected to arsenical solutions are frequently in such a weakened condition that they can not emerge from the eggshell, or they may become lodged in the opening of the ruptured shell and fail to extricate themselves, or show such slowness of movements after emerging as to make one believe that they could not effect a successful attachment after reaching a host, a condition of the larvæ which has also been noticed in the case of eggs subjected to unfavorable conditions, such as a low relative humidity and low temperatures.

The data relative to the ticks removed from cattle after treatment and their corresponding controls from untreated cattle given in the account of the various experiments are summarized in Tables 1 to 7.

In part A of each table are given the data relative to ticks from treated cattle, and in part B the data relative to ticks from untreated cattle, these being removed from their host on corresponding dates and kept under the same conditions as those from the treated cattle. The data for each lot and its corresponding control are given in the same horizontal line.

Column 1. The figures given in this column refer to the number of the experiment to which each lot of ticks belonged.

Column 2. In this column is given the percentage of arsenic, expressed in terms of arsenic trioxid, which was contained in the dip used in treating the cattle from which the ticks were removed.

[1] This includes all of the different lots of ticks collected from the treated cattle in the various experiments with the exception of experiment No. 5, which is omitted from consideration on account of the fact that the dip used contained an unusually low percentage of arsenic.

Column 3. In this column is given the number of ticks included in each lot removed for observation.

Column 4. The percentage of ticks in each lot which survived to deposit eggs is given in this column.

Column 5. In this column is given the average number of eggs deposited by each tick which survived to deposit eggs. This number was determined either by counting or by weighing the eggs and by calculation from the weight upon the assumption that one egg averages 0.04 milligram in weight.

Column 6. In this column is given for each lot the percentage of eggs hatching.

Columns 7, 8, 9, 10. The data in these columns refer to ticks from untreated cattle and correspond to the data given in columns 3, 4, 5, and 6, respectively.

TABLE 1.—*Results with engorged ticks collected a few hours after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 1 | 0.204 | 6 | 33 | Few. | 0 | 8 | 100 | Normal. | 95 |
| 2 | .172 | 8 | 88 | ...do..... | 0 | 6 | (?) | (?) | 10 |
| 3 | .217 | 15 | 0 | 0 | 0 | 14 | (?) | Normal. | Over 50. |
| 6 | .215 | [1] 57 | 31 | 107 | 0 | (?) | (?) | ...do..... | Many. |
| | | 27 | 37 | 252 | 0 | 17 | 100 | 1,316 | 97 |
| 8 | 0.215–.234 | 46 | 2 | 30 | 0 | 1 | 100 | 1,065 | 40 |
| | | 6 | 50 | 728 | 0 | 40 | 100 | 1,336 | 60 |
| | | 20 | 85 | 481 | 0 | | | | |
| 9 | .225 | 6 | 33 | 328 | 0 | 6 | 100 | 1,083 | 25 |
| | | [2] 14 | 79 | 439 | 0 | | | | |
| | [3] .217 | 11 | 73 | (?) | 0 | | | | |
| | | 3 | 100 | (?) | 5 | | | | |
| 12 | .234 | 37 | 16 | Few. | 0 | 29 | 100 | (?) | 40 |
| | | 2 | 100 | (?) | 0 | | | | |
| | .222 | 59 | 0 | 0 | 0 | | | | |
| | | 18 | 0 | 0 | 0 | | | | |
| 13 | .17 | 38 | 24 | Few. | 0 | 6 | (?) | (?) | 10 |
| | | | | | | 14 | (?) | Normal. | Over 50. |
| 14 | .476 | 49 | 0 | 0 | 0 | [4] 25 | 96 | 316 | 12 |
| 16 | .495 | [1] 43 | 0 | 0 | 0 | [4] 22 | 96 | 505 | 50 |
| | | 19 | 21 | 81 | 0 | | | | |
| 20 | .202 | [5] 30 | 4 | (?) | 0 | [6] 36 | (?) | (?) | 50 |
| 21 | .224 | 100 | 0 | 0 | 0 | 100 | 100 | (?) | ..... |

[1] Engorged and nearly engorged.
[2] One partially engorged.
[3] Oxidized dip.
[4] Partially engorged.
[5] Twenty partially engorged.
[6] Twenty-five partially engorged.

TABLE 2.—*Results with engorged ticks collected one day after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 6 | 0.215 | [1] 24 | 21 | 256 | 0 | 17 | 100 | 1,316 | 97 |
| | | | | | | 1 | 100 | 1,065 | 40 |
| 8 | 0.215–.234 | 32 | 25 | 127 | 0 | 40 | 100 | 1,336 | 60 |
| | | | | | | 5 | (?) | Numerous. | 98 |
| 9 | .225 | 15 | 80 | 609 | 0 | 12 | 100 | 921 | 10 |
| | | 10 | 40 | 322 | 0 | | | | |
| 12 | [2] .217 | 29 | 86 | (?) | 0 | 45 | 100 | (?) | 75 |
| | .234 | 31 | 58 | (?) | 0 | | | | |
| | .222 | 15 | 47 | (?) | 0 | | | | |
| 14 | .476 | [3] 12 | 0 | 0 | 0 | [4] 4 | 100 | 853 | 75 |
| 16 | .495 | [5] 18 | 17 | 413 | 0 | [6] 18 | 100 | 339 | 40 |

[1] Seventeen partially engorged.
[2] Oxidized dip.
[3] Seven partially engorged.
[4] Three partially engorged.
[5] Twelve partially engorged.
[6] Fourteen nearly engorged.

TABLE 3.—*Engorged ticks collected two days after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 1 | 0.204 | 14 | 64 | (?) | 0 | 8 | 100 | Normal. | 95 |
| 6 | .215 | [1] 17 | 24 | 312 | 0 | [2] 8 | 100 | 1,464 | 99 |
| 8 | 0.215–.234 | 6 | 67 | 646 | 0 | 5 | (?) | Numerous. | 98 |
| | | | | | | 40 | 100 | 1,336 | 60 |
| | | 3 | 100 | 478 | 0 | | | | |
| 9 | .225 | [3] 4 | 50 | 419 | 0 | 13 | 100 | 2,076 | 1 |
| | | [4] 29 | 58 | 361 | 0 | | | | |
| | [5] .217 | 8 | 88 | (?) | 0 | | | | |
| 12 | .234 | 12 | 50 | (?) | 0 | 14 | 100 | (?) | 4 |
| | .222 | 6 | 50 | (?) | 0 | | | | |
| 14 | .476 | [6] 6 | 0 | 0 | 0 | [6] 1 | 100 | 737 | 80 |
| 16 | .495 | [4] 14 | 14 | 103 | ..... | [7] 5 | 100 | 777 | 60 |
| 20 | .202 | 48 | 42 | (?) | 1 | [8] 14 | 100 | (?) | 4 |
| | | [8] 26 | 19 | (?) | 0 | | | | |
| | | [9] 60 | 80 | Less than normal. | ..... | [9] 40 | 100 | Normal. | ..... |
| 21 | .224 | [8] 10 | 0 | 0 | ..... | [8] 30 | 10 | (?) | ..... |

[1] Ten partially engorged.
[2] Three partially engorged.
[3] Three nearly engorged.
[4] Eight nearly engorged.
[5] Oxidized dip.
[6] Nearly engorged.
[7] Two partially engorged.
[8] Partially engorged.
[9] Some only partially engorged.

TABLE 4.—*Engorged ticks collected three days after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 6 | 0.215 | [1] 9 | 78 | 612 | 0 | [2] 8 | 100 | 1,464 | 99 |
| 8 | 0.215–.234 | 9 | 11 | 75 | 0 | 40 | 100 | 1,336 | 60 |
| | | | | | | 5 | (?) | Numerous. | 98 |
| 9 | .225 | 4 | 25 | 637 | 0 | 18 | 94 | 784 | 2 |
| | | 1 | 100 | Very few. | 0 | | | | |
| | | [3] 11 | 27 | 310 | 0 | | | | |
| 12 | [4] .217 | 8 | 100 | (?) | 0 | 8 | 100 | (?) | 1 |
| | .234 | 4 | 50 | (?) | 0 | | | | |
| 13 | .17 | 34 | 3 | Few. | 0 | ..... | ..... | ..... | ..... |
| 16 | .495 | [2] 6 | 17 | 732 | 0 | 17 | 100 | 1,316 | 97 |
| | | | | | | 1 | 100 | 1,065 | 40 |
| 20 | .202 | 22 | 45 | (?) | 1 | [5] 14 | (?) | (?) | 10 |
| | | [6] 18 | (?) | (?) | 0 | | | | |

[1] Four nearly engorged.
[2] Three partially engorged.
[3] Three nearly engorged.
[4] Oxidized dip.
[5] Thirteen partially engorged.
[6] Partially engorged.

TABLE 5.—*Engorged ticks collected four days after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 6 | 0.215 | 1 | 100 | 1,400 | 50 | 1 | 100 | 1,787 | 98 |
| 9 | .225 | 1 | 100 | 933 | 0 | 7 | 100 | 1,323 | 1 |
| | | [1] 4 | 0 | 0 | 0 | | | | |
| 12 | [2] .217 | 1 | 100 | (?) | 0 | 2 | 100 | (?) | 0 |
| 20 | .202 | [3] 3 | 0 | 0 | 0 | [3] 3 | (?) | (?) | 60 |
| 21 | .224 | 15 | 40 | Less than normal. | ..... | 15 | 100 | (?) | ..... |
| | | [4] 12 | 0 | 0 | ..... | [4] 12 | 0 | 0 | ..... |

[1] Nearly engorged.
[2] Oxidized dip.
[3] Partially engorged.
[4] Less than half grown.

TABLE 6.—*Engorged ticks collected five days after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 2 | 0.172 | 5 | 20 | 200 | 0 | 14 | (?) | Numerous. | Over 50 |
| | | | | | | 6 | (?) | (?) | 10 |
| 20 | .202 | 1 | 0 | 0 | 0 | [1] 3 | 100 | (?) | 95 |

[1] Two two-thirds engorged.

TABLE 7.—*Engorged ticks collected six days after treatment.*

| A. From treated cattle. | | | | | | B. From untreated cattle (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 20 | 0.202 | [1] 1 | 0 | 0 | 0 | ..... | ..... | ..... | ..... |
| 21 | .224 | 12 | 25 | Less than normal. | ..... | [2] 12 | 100 | (?) | ..... |
| | | 7 | 0 | 0 | ..... | 7 | 0 | 0 | ..... |

[1] Not more than half grown.

[2] Some not fully engorged.

The effects obtained when engorged ticks are taken from untreated cattle and immersed in arsenical dips for a couple of minutes are very much the same as those observed when the ticks are removed from cattle after treatment. (See Table 8.) Sixteen lots, containing from 15 to 123 ticks each, were thus treated. In 5 of the lots none of the ticks oviposited, in the remainder 3 to 100 per cent deposited eggs. In each of the control lots, composed of 4 to 105 ticks each, 95 to 100 per cent of the ticks oviposited. The number of eggs deposited by each treated tick which survived to oviposit averaged much less than in the case of the untreated ticks. In the case of only two lots of treated ticks did any of the eggs hatch. These two lots were treated with a neutral and alkaline solution, respectively, of sodium arsenate equivalent to 0.22 per cent arsenic trioxid, and only 1 and 2 per cent, respectively, of the eggs hatched. In the control lot 99 per cent of the eggs hatched. In view of the close correspondence between the results of the experiments in which engorged ticks were kept under observation after their removal from treated cattle and those in which engorged ticks were removed from untreated cattle and kept under observation after immersion for a short time in arsenical dips, it is evident that experiments of the latter kind are useful in that they furnish an indication of the efficacy of arsenical dips so far as engorged or nearly engorged ticks are concerned.

The arrangement of Table 8 is similar to that of Tables 1 to 7, the data relative to the dipped ticks being given in part A and the data relative to the undipped ticks in part B. The various columns in the table are likewise of similar significance.

TABLE 8.—*Results with engorged ticks dipped in the laboratory.*

| A. Dipped ticks. | | | | | | B. Undipped ticks (controls). | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Experiment No. | Per cent of arsenic in dip. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. | Number of ticks. | Per cent ovipositing. | Number of eggs per tick. | Per cent hatching. |
| 4 | 0.213 | 123 | 82 | 712 | 0 | 105 | 100 | 3,189 | 99 |
| 7 | .215 | 15 | 0 | 0 | 0 | 8 | 100 | 1,464 | 99 |
| | | 51 | 0 | 0 | 0 | 40 | 100 | 1,336 | 60 |
| | [1].217 | 16 | 13 | Few. | 0 | 16 | 100 | (?) | 40 |
| | .24 | 16 | 7 | 12 | 0 | | | | |
| | [1].217 | 15 | 60 | Few. | 0 | ..... | ..... | ..... | ..... |
| 11 | .24 | 15 | 0 | 0 | 0 | ..... | ..... | ..... | ..... |
| | [1].217 | 22 | 14 | Few. | 0 | 22 | 95 | (?) | 25 |
| | .24 | 22 | 0 | 0 | 0 | | | | |
| | .24 | 21 | 14 | Few. | 0 | 21 | 95 | (?) | 75 |
| 15 | .476 | 46 | 4 | 98 | 0 | 46 | 98 | 1,443 | 98 |
| | | | | | | 4 | 100 | 853 | 75 |
| 17 | .495 | 59 | 3 | 150 | 0 | 59 | 98 | 1,195 | 97 |
| 18 | [2].22 | 20 | 95 | (?) | 1 | 20 | 100 | (?) | 99 |
| | [3].22 | 20 | 100 | (?) | 2 | | | | |
| 19 | [4].22 | 22 | 86 | (?) | 0 | 22 | 100 | (?) | 1 |
| | .22 | 22 | 0 | 0 | 0 | | | | |

[1] Oxidized dip.
[2] Sodium arsenate (neutral).
[3] Sodium arsenate (alkaline).
[4] Sodium sulpharsenite.

No more is known as to the exact way in which the poisonous action of arsenic takes effect upon the eggs of ticks than is known as to the way in which it takes effect upon the ticks themselves. The fact that the eggs have been injured becomes apparent soon after deposition, sometimes immediately. Those which have been injuriously affected are then readily distinguished by their dark color and shriveled condition. The two series of photographs given in Plates I to VI, in which the appearance of treated and untreated ticks may be compared, show very strikingly some of the effects of arsenical dips upon ticks and their eggs.

Summing up the numerous observations which have been made as to the effects of arsenical dips upon engorged, partially engorged, and young female ticks, it will be noted (1) that cattle were generally free from engorged ticks within a week after treatment; (2) that of the ticks which were present in the engorged stage at the time of treatment or which subsequently reached the engorged stage, only a few, as a rule, deposited eggs; (3) that the number of eggs deposited was much less than normal; and (4) that very few of the eggs hatched.

### MALE TICKS.

Very few male ticks were found alive on cattle later than a day or two after treatment, and it is probable that most of these were ticks which were in the nymphal stage at the time of treatment. It may therefore be concluded that arsenical dips are highly efficacious so far as the destruction of male ticks is concerned.

NYMPHS AND LARVÆ.

It was found in the experiments with arsenical dips that the vast majority of nymphs were killed by a single treatment. In several experiments, however, some of the nymphs survived and afterwards molted. Supplementing the observations made on nymphs in situ on cattle after treatment, observations were made on nymphs removed from their hosts subsequent to treatment after the lapse of varying periods of time. (See Table 9.) These observations showed that in the case of 12 lots none of the nymphs molted; and that in the case of four lots 8 to 50 per cent molted. Nymphs removed from untreated cattle and kept under the same conditions, as controls, usually molted, 10 to 100 per cent in nine lots, only one lot being collected in which all the nymphs failed to molt.

In Table 9 are given data, summarized from the various experiments, relative to the molting of nymphs removed from cattle after varying periods of time subsequent to treatment, as compared with the molting of nymphs removed on corresponding dates from untreated cattle.

Part A refers to nymphs from treated cattle, and part B to nymphs from untreated cattle removed on corresponding dates and kept under similar conditions.

Column 1. In this column is given the number of the experiment to which each lot of nymphs belonged.

Column 2. In this column is given the percentage of arsenic, expressed in terms of arsenic trioxid, which was contained in the dip used in treating the cattle from which the ticks were removed.

Column 3. The figures in this column refer to the number of days which elapsed from the time the cattle were treated until the nymphs were removed.

Column 4. In this column is given the number of nymphs included in each lot removed for observation.

Column 5. The percentage of nymphs which molted subsequent to removal from their host is given in this column.

Column 6. In this column is given the number of nymphs in each lot removed from untreated cattle.

Column 7. The percentage of nymphs which molted subsequent to their removal from untreated cattle is given in this column.

TABLE 9.—*Results with nymphs collected from dipped and undipped cattle.*

| A. From treated cattle. | | | | | B. From untreated cattle (controls). | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Experiment No. | Per cent of arsenic in dip. | Number of days. | Number of ticks. | Per cent which molted. | Number of ticks. | Per cent which molted. |
| 1 | 0.204 | 2 | 4 | 50 | 14 | 79 |
| | | 7 | 13 | 8 | | |
| 2 | 0.172 | 5 | 69 | 0 | 25 | 84 |
| | | 8 | 7 | 0 | | |
| 3 | 0.217 | 0 | 6 | 33 | 4 | 75 |
| 13 | 0.17 | 14 hours. | 10 | 0 | 25 | 84 |
| | | 3 | 9 | 0 | | |
| | | 0 | 12 | 0 | 20 | 95 |
| | | 2 | 17 | 0 | 2 | 100 |
| 20 | 0.202 | 3 | 41 | 0 | | |
| | | 4 | 54 | 0 | 42 | 64 |
| | | 5 | 46 | 0 | 12 | 83 |
| | | 6 | 1 | 0 | | |
| | | 2 | 15 | 0 | 20 | 10 |
| 21 | 0.224 | 4 | 15 | 13 | 15 | 20 |
| | | 6 | 4 | 0 | 4 | 0 |

No instance was observed in any of the experiments of the survival of ticks in the larval stage after a single treatment with an arsenical dip. While the possibility of such an occurrence must be admitted, it seems certain that the survival of larvæ after treatment with an arsenical dip of proper strength would be very exceptional, and for practical purposes it seems safe to assume, until evidence can be obtained to the contrary, that arsenical dips are entirely efficacious so far as concerns ticks in the larval stage.

## THE PROTECTIVE ACTION OF ARSENICAL DIPS.

Little evidence has been obtained as to the degree of protection against reinfestation afforded by arsenical dips or as to the length of time after treatment that such protective action continues. It seems, however, that cattle are protected from reinfestation, at least to some extent, during several days after treatment. The results obtained by Watkins-Pitchford with regard to the accumulation of arsenic in the skin and the toxicity of regularly treated animals, already referred to, would seem to show that an arsenical dip may protect cattle considerably against reinfestation. Owing to the uncertainty as to this point, however, it is unsafe to place any reliance upon the protective action of arsenical dips, and it should be assumed that treated cattle are liable to reinfestation if exposed at any time after the arsenical solution has become dry upon their bodies.

## PRACTICAL SIGNIFICANCE OF RESULTS OF EXPERIMENTS WITH ARSENICAL DIPS.

In considering the practical application of the results of the experiments with arsenical dips, it should first of all be noted that although arsenic has a marked effect on all stages of the tick, none of the arsenical dips tested has proved sufficiently efficacious to insure a tick-free condition of cattle by means of a single application of the dip. As we know them at present, therefore, arsenical dips must be considered as falling short of the ideal of perfect efficacy.

The question then arises whether with their admitted imperfections arsenical dips may be used with advantage in the eradication of ticks. This question may be unhesitatingly answered in the affirmative. Arsenical dips are undoubtedly of very great value in tick eradication, and all things considered no better dip for the destruction of ticks has yet been discovered. This has been demonstrated not only by experimental work, but also by the results obtained from an extensive practical use of arsenical dips by many owners of live stock in Texas, Oklahoma, and California.

The practical application of the results of the experiments with arsenical dips may be considered under the following heads: (1) Composition of the dip; (2) method of application; (3) number and frequency of applications; (4) handling the cattle.

### COMPOSITION OF THE DIP.

The investigations thus far carried out have not been extensive enough to enable a definite statement to be made as to the minimum percentage of arsenic required to give an arsenical dip a sufficiently high degree of efficacy to make it of practical value. Moreover, it is probable that a stronger dip will be necessary to obtain satisfactory results under some conditions than under others, and it is probable also that in many cases a rather weak dip may be used to advantage when a stronger dip would be undesirable on account of possible injurious effects on cattle, as, for example, in the case of repeated treatments during very hot weather.

The experiments indicate that dips containing as high as 0.24 per cent arsenic (reckoned as arsenic trixoid) may be used without unduly injuring cattle. It has been assumed that this is the maximum strength at which dips containing arsenic in the form of sodium arsenite or potassium arsenite may be used without too great risk of injury. In view of the fact that in one experiment (No. 5) an arsenical dip containing somewhat less than an equivalent of 0.2 per cent proved less efficacious than dips in other experiments which contained an equivalent of approximately 0.2 per cent or more of arsenic trioxid, 0.2 per cent was selected as an arbitrary minimum limit. The mean between

the minimum and maximum limits, or 0.22 per cent, may therefore be taken as an arbitrary standard, and a dip to have the maximum degree of efficacy, so far as this may be attained without great risk of injury to cattle, should not deviate more than very slightly above or below this standard of 0.22 per cent.

The arsenical dips commonly used and with special reference to which most of the experimental work has been done are based on a modification of Dr. Mayo's formula given in the introduction of the present article. Directions for preparing such a dip so that it will conform to the standard which has been selected are as follows:

In preparing each 500 gallons of the standard arsenical solution there shall be used 10 pounds of finely powdered white arsenic containing not less than 99 per cent of arsenic trioxid, 25 pounds of sal soda, and 1 gallon of pine tar. The arsenic and sal soda shall be boiled together in not less than 25 gallons of water for fifteen minutes, or longer if necessary to effect complete solution of the arsenic. Before the pine tar is added, the temperature of the solution shall be reduced to 140° F. This may be done by the addition of cold water. The pine tar shall then be added in a small stream while the solution is thoroughly stirred, after which the solution shall be immediately diluted with clear water sufficient to make 500 gallons of dip.

The cooling of the arsenic and sal soda solution before the addition of the pine tar is important, as otherwise an imperfect mixture having a curdled appearance is likely to result.

It has already been noted that the quantity of sal soda used in the above formula is in excess of the amount actually needed to combine with all the arsenic, but until it can be shown that the efficacy of the dip in no way depends upon the presence of this excess of soda, the proportionate amount of sal soda should not be reduced.

In cases wherein it is considered expedient to use a weaker dip the amount of arsenic may be reduced to 8 pounds per 500 gallons of dip, but for all official dippings the standard amount of 10 pounds to 500 gallons is required.

### METHOD OF APPLICATION.

There are two practicable methods of applying arsenical dips, namely, by spraying and by dipping.

Spraying is not practicable except in the case of very small herds, unless a spraying machine is used. Spraying machines, however, have proved less satisfactory than dipping vats, and it is therefore preferable to use a dipping vat whenever more cattle are to be treated than it is practicable to treat by means of hand spray pumps. Hand spraying is not only more tedious than dipping, but it is also less efficacious, as there is not the same certainty of getting a thorough application of the dip even when the greatest care is used. Consequently the dipping vat is much more reliable than the spray pump. It is also more economical whenever more than a very few animals are to be treated.

A dipping vat for cattle should be large enough to afford a bath at least 5¼ feet in depth, and unless the cattle when dipped are held in the bath, the vat should measure at least 40 feet in length at the surface of the dip. If a shorter vat is used the cattle should be held in the bath at least 15 seconds—half a minute would be better—otherwise they are liable to get through the bath without being thoroughly wet to the skin, particularly if the hair is long. A steep slide at the entrance of the vat is desirable in order to insure a plunge which will carry the cattle entirely under the surface of the bath.[1]

### NUMBER AND FREQUENCY OF APPLICATIONS.

From the data obtained in the experimental work it appears that one treatment with an arsenical dip is insufficient to free cattle from ticks. Subsequent to dipping, ticks continue to reach engorgement and fall from the cattle for several days and a few nymphs are liable to survive, molt, and possibly continue their development to the engorged stage. On the other hand, no instance has been recorded in which a tick survived and reached fertile maturity after two thorough applicatons of an arsenical dip given 7 to 10 days apart, and no larvæ have been observed that have survived a single treatment. The results of the experiments therefore show that cattle may be freed from ticks by two treatments with an arsenical dip.

Although the possibility of ticks surviving two treatments and maintaining the ability to reproduce is always present, the experimental work shows that such an occurrence must be very rare, provided the treatments are thorough, and it is therefore proper to assume, as a working basis, that two treatments are entirely efficacious. Accordingly it may be stated as a tentative conclusion that after two thorough treatments cattle may be placed on uninfested ground with practically no danger of carrying with them any ticks capable of perpetuating the species. In practice, therefore, when cattle are to be treated for the purpose of ridding them of ticks so that they may be put in uninfested pastures or other tick-free places, they should be dipped twice with an interval of 7 to 10 days between dippings, using a full-strength arsenical dip.

When cattle are to continue occupying the same pasture or range the question of the number and frequency of treatments is somewhat different. In this case the rule would be to give repeated treatments at intervals of not over three weeks. Usually more than three weeks and rarely less than this time is required for larval ticks after reaching a host to complete their development to the engorged stage. Hence if cattle were treated every three weeks practically all of the ticks which they picked up in the meantime would be subjected to

[1] The Bureau of Animal Industry is prepared to furnish plans and specifications for dipping vats to persons contemplating the construction of vats.

treatment. Scarcely any would escape and deposit eggs, and when it is considered that the average number of eggs deposited by each tick surviving treatment would be less than normal, and that only a small proportion would hatch, it is evident that the amount of infestation of cattle and pastures would greatly and rapidly diminish. Practical experience has demonstrated that complete eradication may be accomplished in this way, the probable explanation being that even if ticks occasionally survive dipping the number is reduced below the minimum necessary to insure the survival of the species. In other words, in those localities where ticks are established, their fecundity is sufficient for the perpetuation of the species under ordinary conditions, but if the vast majority of individuals that find a host are destroyed, a point is soon reached in the numerical reduction below which it is impossible for the species to maintain itself. No set rule can be formulated at present as to the number of times it will be necessary to repeat the treatment with the arsenical dip to bring about eradication, but a general rule would be to continue the treatment until the ticks had apparently disappeared, then discontinue it, and if at any time ticks are again observed, resume the treatment, keeping always on the lookout for signs of ticks, just as a physician, in the case of diseases liable to reappear when apparently cured, watches for symptoms indicating a recurrence of the malady.

### HANDLING THE CATTLE.

Cattle should not be treated with arsenical dips when tired or thirsty, and after treatment should not be allowed to drain in places where the drippings from their bodies will form pools which they may drink, or where grass or fodder will become soaked with the dip. For a week or so after treatment, especially in hot weather, cattle should not be driven hard or allowed to run or become overheated. After treatment cattle may, however, be safely shipped by rail, even though they are loaded as soon as their bodies become dry.

When cattle are to be freed from ticks by two treatments a special arrangement of the dipping plant and yards for handling the cattle is necessary, so that after the second dipping they will not be exposed to reinfestation. Certain yards and the alleyways leading to them from the draining pen must be reserved exclusively for cattle which have been twice dipped. These yards and alleyways must be free from infection and must not be used for any cattle except those which have been twice dipped or are known to be free from ticks. For several days after the first dipping cattle are likely still to harbor ticks able to reproduce, hence it is unsafe to place them in yards or pastures which it is desirable to keep free from infection, and as the second dipping will destroy any larvæ which they may pick up in the

meantime, cattle should be kept between dippings in places which are either definitely known to be infested, or which it is not desired to be kept free from ticks. After the second dipping, however, cattle must be guarded from exposure to infection, hence from the time they leave the draining pens they must not pass over or occupy any places infested with ticks. In order thus to handle cattle either two dipping vats will be required, or, if the same vat is used for both dippings, some arrangement must be made whereby cattle may be

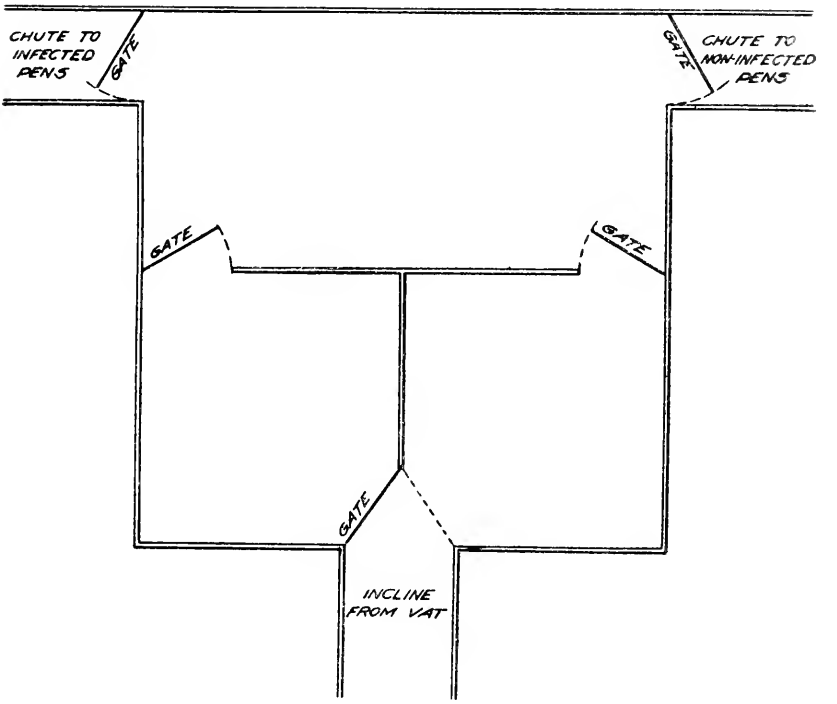



FIG. 1.—Plan of draining pen for cattle after dipping.

brought from the draining pens to their respective yards after the first and second dippings by entirely distinct routes. This may be readily done when a single draining pen is used if the two alleyways for once-dipped and twice-dipped cattle, respectively, lead away in different directions from the draining pen. If, however, the common type of double draining pen is used it will be necessary to add a third section (as shown in the plan) in order that separate routes for once-dipped and twice-dipped cattle may be provided for.

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